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HUMAN DEVELOPMENT

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PREFACE

This book grew out of the need for a text that would cover the entire age span from conception to old age, devoting about the same amount of space to each period of life. In the past decade, interest has grown in psychological and physiological studies of maturity and old age. Research in this area has been vigorous. We have attempted to bring this material—still scattered throughout various journals—into line with the more extensive body of knowledge on behavioral development during childhood and adolescence and in this way to provide a continuous picture of human development and subsequent decline. For the sake of clarity we have used a longitudinal approach consistently, tracing an aspect of behavior from its genesis in the prenatal or early postnatal stages through adulthood to old age.

Since we believe that no thorough understanding of human development can be achieved without a regard for phylogenetic changes as we ascend the scale from the lowest invertebrates to man, we have begun most chapters with a brief description of the phylogenetic aspects of sensory processes, learning, emotions, etc., following this with ontogenetic changes in the various behavioral areas. Discussions on phylogenesis are brief, however, and, at the discretion of the teacher may easily be omitted without disruption of the continuity of the ontogenetic sequence.

The experimental literature on psychological development during childhood and adolescence is extensive, and several excellent texts are already available for these periods. We have therefore been highly selective in our treatment of early life, choosing only the more important studies, especially those which give a clear picture of behavior at the various age levels. This principle of selection is particularly evident in chapters dealing with motor processes, language, and intelligence, as well as emotional, social, and personality development. Throughout the various chapters, however, we have cited references to review articles and books which amplify a specific topic. Our treatment of the literature covering maturity and old age is more exhaustive, since many of these studies have not yet been included in any textbook.

The general orientation of this book is physiological. In the early chapters we have given a fairly extensive treatment of age changes in the neural and glandular systems, for example. These body systems were

singled out for study because we believe that in the later years many of the behavioral changes in sensory and motor processes, in interests, and in learning, memory, and other intellectual functions are to some degree manifestations of structural and functional changes of these systems.

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J. P. Zubek
P. A. Solberg

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INTRODUCTION

In this book, we shall survey the extensive physical and psychological changes that occur throughout the course of life from conception through birth, childhood, adolescence, and maturity to old age. Most texts in developmental psychology are limited to descriptions of expanding behavior in childhood and adolescence, as though development ended there; they neglect to mention that exceedingly important changes continue to occur in subsequent years. It has been rightly stated, however, that developmental psychology is "concerned not only with emerging capacities and expanding behavior but also with declining abilities and behavior restrictions in old age" (Kuhlen and Thompson, 1952). Accordingly, we propose to deal not only with early life but also with the changes of maturity and the later years, which have been relatively neglected by writers in this field.

In addition to discussing age changes in the various processes in man, we shall briefly describe their evolutionary development in animals, ranging from the simplest to the most complex, for it is our belief that some knowledge of the development of these fundamental physical and psychological processes in lower animals promotes a better understanding of human beings. Thus, our aim is twofold: to trace the course of development of basic processes (1) in animals, ranging from the single-celled organisms to man, and (2) in man, from conception to old age.

This first chapter offers a preview of material to be discussed later in more detail. First, our approach to the study of human development will be described. This will be followed by a brief outline of the next 14 chapters. Finally, some of the general principles underlying human development and behavior will be set forth.

APPROACH OF BOOK

Our approach, schematically illustrated in Fig. 1, is somewhat different from what is to be found in the usual developmental psychology text. For that reason we shall begin by clarifying it. As can be seen in the diagram, we represent human development by two continuums, one phylogenetic and the other ontogenetic.

Phylogenesis. The horizontal axis, or abscissa, of Fig. 1 illustrates *phylogenesis*, more commonly known as evolution. The animal kingdom to which man belongs can be roughly divided into a dozen major divisions, called *phyla*, and further subdivided into classes, orders, genera, and species. In Fig. 1 are listed most of the important phyla with some representative species of each, ranging from the one-celled protozoa to mammals. The fact that different phyla are placed at intervals along the
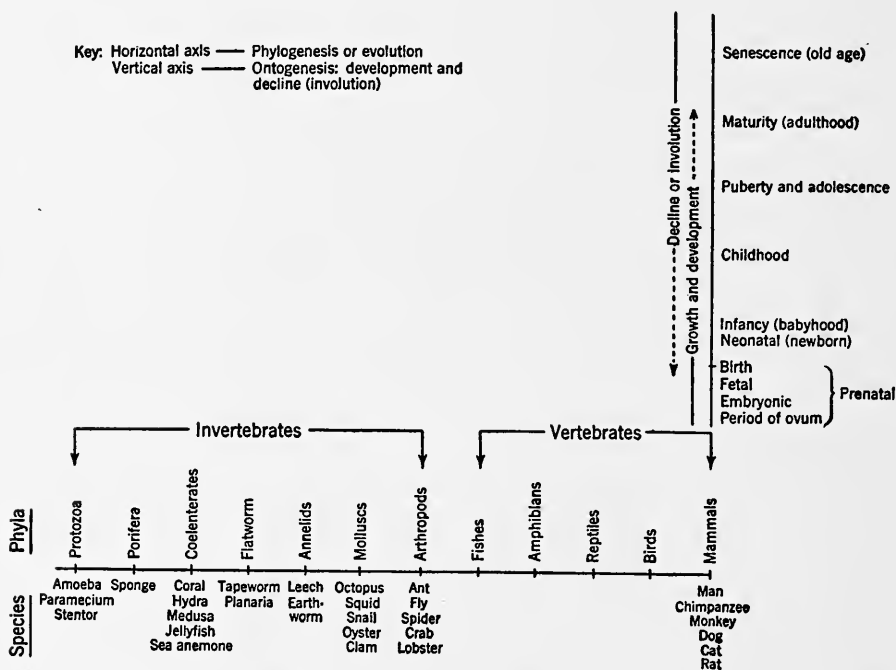
FIG. 1. Schematic representation of human development along two continuums: phylogenetic and ontogenetic. Note that decline (involution) begins in the prenatal period and that growth continues into the later years of life.

abscissa does not necessarily mean that evolution proceeded in this order —for example, that fishes evolved from arthropods or mammals from birds. The schema is purely a graphical convenience illustrating a general trend toward increasing complexity in structure and function as we proceed from left to right along the continuum. This schema will be used in subsequent chapters dealing with evolutionary changes in such physical and psychological processes as vision, learning, emotions, and social behavior.

Ontogenesis. Whereas 'phylogenesis is concerned with changes in the various processes of different animals, proceeding from the simplest to the more complex, *ontogenesis* refers to changes in any organism through-

out its lifetime. In Fig. 1, ontogenesis is represented along the ordinate, or vertical axis. This is a true continuum, beginning with conception and ending with death. Such a vertical line could readily be drawn through any point along the base line to illustrate the aging process in any organism. We are especially interested in human beings, however, and so the demarcations represent the more common developmental periods of man.

Major Periods in Ontogenetic Development. As a result of research on individuals of different ages, it has been found that the human life span may be divided roughly into seven major periods, each characterized by certain specific developmental features. Although these periods overlap considerably, they coincide closely enough with certain chronological ages to facilitate discussion.

First is the *prenatal period,* extending from conception to birth. This relatively short phase of 280 days is distinguished by more rapid growth and development than any other time of life. It is often subdivided into three stages: (1) the *period of the ovum,* beginning with fertilization of the ovum, or egg, and lasting until the end of the second week, when the organism becomes an embryo; (2) the *embryonic period,* extending to the end of the second month; and (3) the *fetal period,* which covers the remainder of prenatal life. These stages will be discussed further in Chapter 3.

For the first 2 weeks after birth the newborn organism is known as a *neonate.* The neonatal period is chiefly an interval of incipient adjustment to a totally new environment. It merges into *infancy,* or babyhood, which lasts well into the third year. Although infancy is a time of helplessness and reliance on others, it is an important period, for during these early years the basic elements of speech, locomotion, and control of body activities are established.

Childhood extends from infancy to puberty, although investigators frequently use this term to designate the entire span from birth to puberty. During childhood, control over the body improves tremendously through maturation and through constant practice in jumping, running, cycling, climbing, and a host of other physical activities. Through language as well as the motor skills the child is able to control his environment to a greater extent and to participate in social activities.

Puberty, or sexual maturation, reached at the beginning of the teens, introduces *adolescence,* which extends to about the age of 21. Since this is a relatively long period, it is often subdivided into early and late adolescence. Early adolescence, from age 11 to 13 to around age 16 or 17, roughly coincides with the high-school years and is characterized by pronounced physical and psychological changes, which will be described in later chapters. Late adolescence coincides fairly closely with the college years and is marked by a keen interest in the opposite sex, by emancipation from the parental home, and by definite vocational plans. At the

close of this period the individual is regarded as legally mature in our society.

During *maturity* the individual stands on his own feet. He makes his own decisions, establishes his own home, and through his own efforts supports both himself and his family. Physically, he is at the peak of performance and endurance; emotionally, he is able to inhibit overt outbursts and to ignore minor stimuli; intellectually, he is able to think clearly and objectively and to maintain an open mind; socially, he exhibits mature interest in the problems of his society.

Since the peak of development is not achieved simultaneously from all viewpoints and since individual differences are great, it is difficult to appraise the various maturities in terms of chronological age. Some body structures and processes may have virtually completed their growth during the teens; others may continue to develop well into adult life. Thus, bones achieve maximum length in adolescence, but bone weight does not reach its peak until around the age of 35 and maximal muscular development falls closer to age 50 (see Chapter 5). Similarly, investigators place the peak of intellectual development in the middle teens (see Chapter 10), but the ability to think objectively is a mature characteristic—indeed, some never achieve it at any age. Accordingly, no rigid age boundary can be fixed between adolescence and adulthood. As will be seen, it is wisest to regard the limits as flexible and then to think in terms of early maturity as extending from around age 21 to age 45 or 50, when it merges into later maturity until the age of 65.

Finally we come to old age, or *senescence*. Some individuals are old at 45; others are youthful at 70. Regardless of this, there is sufficient evidence to fix the beginning of senescence at about 65 for, as will be seen, decline may begin earlier but becomes much more conspicuous at this time. Sixty-five is also the usual age of retirement from work, and this is often reflected in changed behavior and adjustment.

Recent Interest in Old Age. It is only recently that investigators have begun to show any interest in old age. During the past decade, however, research has been both extensive and intensive, and three new scientific journals have been devoted entirely to this period of life. Words such as gerontology and geriatrics, almost unknown before, now appear frequently in popular magazines as well as in the scientific literature. It is important to understand their precise meanings: *gerontology* refers to the scientific study of old people; *geriatrics*, to the branch of medicine concerned with studying and treating the diseases of the aged. In this book we are especially concerned with gerontological studies, that is, studies which throw light on the capacities of our normally aging population.

Several reasons contribute to this great postwar interest in aging. Perhaps the most important factor is the increasing proportion of old people.

in our population. In 1900, roughly 3 million persons in the United States were 65 years old or more (4 per cent of the entire population); today, this number has increased to over 13 million (approximately 9 per cent of the population), and the upward trend is continuing (see Gilbert, 1952). We therefore need to know more about the abilities, interests, and adjustment of our senior citizens. Because of this recent interest in old age and because so much of the research in this area has not yet been well assembled, we shall give considerable attention to behavioral characteristics of this segment of our population.

Longitudinal Approach. There are two avenues of approach to the study of ontogenetic development. A cross-sectional approach describes the main developmental features of childhood, adolescence, or old age in such a way as to give a complete picture of the individual at each age period. A longitudinal approach traces some aspect of behavior—*e.g.*, sensory, learning, or emotional—directly through from genesis to decline, giving a complete picture of one process throughout life. Phylogenesis lends itself to similar treatment: a cross-sectional survey would deal with each phylum in turn, while a longitudinal study would trace the evolution of vision or learning through the phylogenetic sequence, proceeding from the simplest organism to the more complex.

Both approaches have advantages and disadvantages. In this book we have found it more convenient to use the longitudinal approach. In Chapter 9, for example, under the heading of Learning, we shall first look at the nature of learning ability in different organisms from protozoa to man; next we shall examine the nature and main characteristics of human learning, and finally we shall trace the changes in learning ability from the prenatal stage through to old age. Again, in Chapter 3, we shall begin with a brief discussion of the evolution of the nervous system, then examine its structure and function in human beings, and finally trace its development from conception through the growing years and its deterioration in old age. This approach will be used in all chapters in so far as feasible.

PREVIEW OF BOOK

Human development is a broad topic. It will therefore be helpful to glimpse in advance the subject matter of the text as a whole so that each chapter can be seen as a part of the larger picture.

Summary of Chapters. Since human development begins with conception, we too shall begin with a discussion of the genetic foundations of behavior. The findings of the science of genetics are fundamental to our understanding of both phylogenesis and ontogenesis. No matter how simple or how complex the organism, it begins life as a single cell. Why, then,

do some such cells develop into human beings while others become lower animals? Why do some become males and others females? Why are the physical and psychological characteristics of children more like those of parents and siblings than like those of unrelated individuals? These and other important questions will be discussed in Chapter 2.

The single cell gives rise to a complex organism whose behavior depends largely on its physical make-up. Physical changes profoundly influence motor, intellectual, emotional, and other behavioral characteristics. For this reason, the next unit, consisting of Chapters 3, 4, and 5, deals with the physical structure and function of man. Most important to behavior, perhaps, is the nervous system; accordingly, it is placed first in Chapter 3. Development of the nervous system has widespread effects: it contributes to the increase of locomotor and manual skills enabling us to move around and to manipulate our environment; it is reflected in sensory and intellectual growth, contributing in turn to greater understanding and hence to more effective control of the world around us. Deterioration of the nervous system in later years is reflected in poorer coordination of body movements, increasing difficulty in learning new things, declining memory, diminishing powers of comprehension, and increasing difficulty in changing our habitual way of doing things.

Chapter 4, the second chapter of this sequence, describes the glandular system, whose well-being promotes normal physical, mental, and emotional development and functioning. Increased endocrine output at the time of puberty, for example, brings about the physical growth spurt and promotes an interest in the opposite sex; diminished output in old age results in decreased bodily vigor and certain changes in interests, attitudes, etc. Chapter 5 deals with the internal organs responsible for circulation, respiration, digestion, and excretion—all essential to good health and normal behavior. Topics such as height and weight, changes in skeleton, muscles, and general physical appearance are also included, for they are important in determining how others react to us and (perhaps even more significant) how we regard ourselves.

Chapter 6, which might well be included in the physical sequence, deals with motor development. Locomotor and manipulative abilities limit the kinds of activities in which we can participate at every age. Once a child becomes mobile, he can share in play and other group activities, thereby enlarging the sphere of social influences. Adults require a high degree of motor skill to hold a job and to engage in sports and other recreations. In old age, declining motor abilities again limit the range of activities with marked effects on both work and play.

Closely related to these topics is sensory development, discussed in Chapters 7 and 8. Motor skills may bring us into close contact with a variety of objects in the environment, but it is only through sensory

media that they can influence us. In old age, for example, declining visual and auditory sensitivities may make it difficult to read, to do fine work, or to hear conversation; this decreasing sensitivity to stimuli may make it impossible to accomplish a variety of tasks efficiently.

Of all fundamental processes, learning and intelligence contribute most toward distinguishing us from the lower animals. Learning, memory, language, imagination, and reasoning are considered in Chapters 9 and 10. These processes enable us to adjust to varying situations, to solve the numerous problems confronting us, to devise new ways of dealing with things, and to communicate our findings to others. Not all our actions are governed by mental processes, however, as we will find in Chapter 11, which deals with emotional development. A study of emotions is highly important, for emotions are closely related to happiness and misery and play a part in determining beliefs, values, attitudes, and general adjustment.

The book thus far is primarily concerned with the development and decline of physical and mental capacities and their relation to the physical world. The next unit, including Chapters 12, 13, and 14, is concerned with social influences. At birth we are neither social nor antisocial but rather asocial creatures. Gradually we learn to adjust to fellow human beings of different sex, age, and social background. This socialization process is described in Chapter 12. Related to it are the topics of interests and attitudes which follow in Chapters 13 and 14. A person's interests tell us a good deal about the influences to which he has been exposed: movies, radio, television, newspapers, college, or travel, for example. Such influences affect us at most ages, playing their role in determining values and attitudes as well as interests.

The last chapter concerns personality—perhaps the most difficult aspect of human development to study. Here we deal with individuality —the characteristics which set each person apart from others of his kind and give him a unique place in the group. First a few examples of techniques for appraising personality will be given; next the emergence of personality traits and the extent to which they tend to persist throughout life will be considered.

Cross-sectional vs. Longitudinal Studies. As the course of human development is followed from chapter to chapter, it can be seen that the picture presented here is based almost entirely on cross-sectional studies; only rarely is reference made to longitudinal investigations. Let us stop for a minute to see what this means.

Cross-sectional studies gather data from groups of individuals who represent the different age groups at the time each survey is made. Longitudinal studies, on the other hand, follow the progress of the same subjects from year to year, noting changes as they occur. Let us use as

an example a study of age changes in learning ability through elementary school and high school. The cross-sectional study would make use of several age groups, perhaps 6-, 10-, 15-, and 18-year-olds. Tests of learning ability would be given to all subjects at once, and the average scores for each age group would be plotted graphically to produce a learning curve representing mental growth from 6 to 18 years. In a longitudinal study, similar tests would be given to a group of 6-year-old children on entering school. The same children would then be retested every year or two until they reached the age of 18. At that time the average scores for successive tests would be plotted to produce the growth curve.

This example shows clearly why cross-sectional studies are so numerous and longitudinal surveys so rare. Cross-sectional studies are much less time-consuming and less expensive, since the investigator can test all subjects simultaneously without waiting for them to grow up. In many areas of research, this method has been used almost exclusively (*e.g.*, norms for height or weight). Among the several weaknesses of cross-sectional investigations, perhaps the most serious is the problem of getting comparable groups at the different age levels. An investigator who wished to appraise attitude changes during college, for example, would have no trouble in getting sufficient numbers of first- and fourth-year students but would have considerable difficulty in ensuring that the two groups were comparable. By the senior year many students have dropped out because of insufficient learning ability, inadequate finances, lack of drive, or a host of other reasons. Thus, the seniors might differ in many respects from the freshman sample. To get around this difficulty, large samples of carefully matched subjects would be needed. Only to the extent to which this is done can any confidence be placed in the findings of cross-sectional investigations.

Longitudinal studies present a truer picture of development. Although not as large samples are required, this method is arduous, time-consuming, and expensive. Despite the difficulties involved, there are a number of excellent longitudinal studies on some aspects of development. Attention will be drawn to them in later chapters.

SOME GENERAL PRINCIPLES OF HUMAN DEVELOPMENT

Several basic principles underlie human development and decline. Let us consider them carefully, for they will help us to understand many apparently contradictory studies reported in the following chapters.

Development and Decline Proceed Simultaneously. At first thought it might seem that the early years of life are characterized solely by growth and development of various physical and psychological capacities and the later years solely by deterioration. If we examine this problem more

closely, however, we will find that development and decline proceed concurrently throughout the life span, although they vary in *rate* and in *degree* (Stieglitz, 1949). During infancy and childhood, growth predominates but degenerative changes have nevertheless begun. For example, it will be pointed out later that certain neurons are lost as early as the embryonic stage, that taste buds begin to decrease in number during the fetal period, that certain teeth disappear even in early childhood, and that the thymus gland begins to shrink in size at about the age of 12 (see Hamburger and Levi-Montalcini, 1949; Arey *et al.*, 1935). At the other end of the continuum, it will be seen that, although evidences of growth diminish with advancing years, old age is not entirely a period of degeneration. Certain parts of the autonomic nervous system, for instance, continue to differentiate and to increase in complexity well into old age (Kuntz, 1938). The ratio of development to decline shifts gradually: prior to the age of 40, development predominates; after the fortieth year, the scales begin to dip in the direction of decline (Stieglitz, 1949).

Development Ceases at Different Ages for Different Functions. Textbooks on childhood and adolescence often give the impression that the maximum growth of physical and psychological functions is achieved by late adolescence or that growth stops when the book stops. Although this may apply in a few cases, in general it is untrue. A few examples are sufficient to show this: the maximum number of skin receptors is present by the age of 10 (Ronge, 1943); the peak of bone weight occurs at 35 (Ingalls, 1931); the maximal bulk and density of skeletal muscles is attained at 50 years (Todd, 1942); and, as has already been mentioned, some parts of the nervous system continue to differentiate in old age. Again, considering the components of intelligence measured by tests of numerical completion, common sense, or analogies, the peak of performance can be seen to occur in the late teens; performance on vocabulary tests, however, may continue to improve well into the 70's—at least in subjects of superior ability (see Chapter 10). Thus we find the culmination of growth and development of different functions occurring at different ages.

Decline Begins at Different Ages for Different Functions. Just as different functions reach their growth peak at different ages, so they begin to decline at different times of life. We have already noted that taste buds, for example, begin to decrease in number during the fetal period. Loss of nerves of smell begins soon after birth (Smith, 1942); decrease in the number of skin receptors, during the teens (Ronge, 1943); decrease in size of the pupils, during the 30's (Birren *et al.*, 1950a); degenerative changes in the retina, during the 50's (Friedenwald, 1952); and degenerative changes in the skeletal muscles, sometime in the 60's (Todd, 1942); while some smooth muscles show no structural changes even in old age

(Häggqvist, 1931). Similar differential decline appears in intellectual and other functions.

Tempo of Development and Decline Is Uneven. Neither development nor decline proceeds at a steady pace. Some periods of life are characterized by accelerated growth, while others show less progress. Conversely, certain periods evidence little decline, while others are marked by a high deterioration rate. Throughout the period of the ovum growth rates are slow; on the other hand, during the embryonic period the organism increases in mass by 2 million per cent in a short interval of 6 weeks, furnishing evidence of the most rapid physical growth rate of the entire life span. From this time on through birth and the early postnatal years, growth continues to move swiftly. The rate slackens during late preschool and early school years until just before puberty, when certain aspects of growth such as height and weight evidence a brief spurt before tapering off at adult level.

If we look at the tempo of decline, we find that many body organs such as the nervous system (especially the cerebellum and the spinal nerves), the inner organs, and the skeleton evidence few deteriorative changes prior to the age of 50 but that regression rates increase once the individual has passed that milestone (see Chapters 3 and 5). Again, most sensory, motor, and intellectual functions decline only slightly between the ages of 30 and 50 but exhibit pronounced changes later, especially after the sixtieth year.

Different Functions Develop and Decline at Different Rates. Although the various periods of life have their own peculiar rates of growth and deterioration, it is important to note that the different functions neither develop nor deteriorate at the same rate within any given period. This is well illustrated by Fig. 2, which shows the differential growth rates of several body systems. The genital system, for example, shows scarcely any growth during the first 12 years but a sudden spurt around puberty; on the other hand, the lymphoid system (*e.g.*, thymus gland) grows rapidly throughout the entire period from birth to the age of 12.

The rate of decline, too, differs for different functions. The lymphoid system degenerates quickly soon after reaching peak development (see Fig. 2); on the other hand, most body systems show little deterioration for several years after reaching mature status, and even when decline begins it is gradual for some time, accelerating only in later life. Perhaps the best illustration of differential decline is found in mental abilities: the ability to do analogy problems drops off *sharply* from the late teens onward; the ability to do numerical problems and assemble dissected sentences declines *gradually* from the late teens; while ability to follow oral directions decreases sharply during the third decade only to *level off* and show no further decline throughout life (Jones and Conrad, 1933).

Various Factors Can Affect the Course of Development and Decline.
The following chapters will show that many factors can affect the course
of both growth and decline. Here are only a few examples.

Sex. One of the most important influences is sex. This appears clearly
when we watch physical growth. At birth boys are slightly bigger than
girls; girls reach puberty earlier than boys, however, and prior to puberty
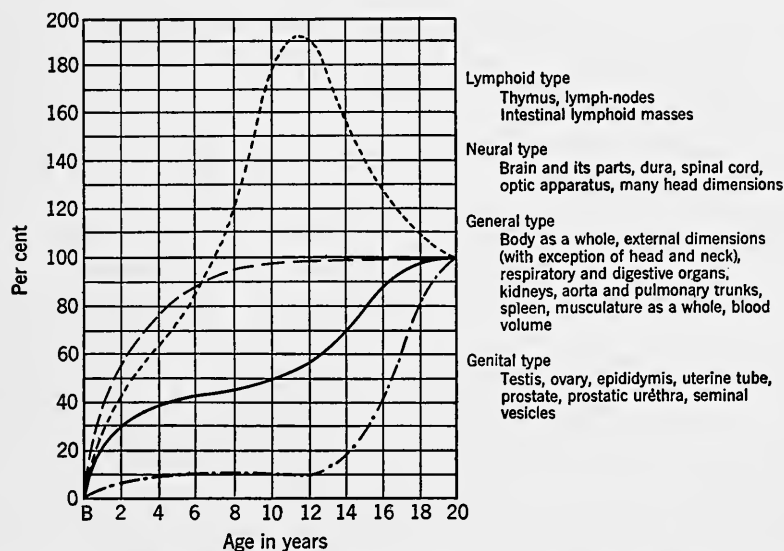grow faster so that for a while they are taller. Sex also influences the time

Lymphoid type
  Thymus, lymph-nodes
  Intestinal lymphoid masses

Neural type
  Brain and its parts, dura, spinal cord,
  optic apparatus, many head dimensions

General type
  Body as a whole, external dimensions
  (with exception of head and neck),
  respiratory and digestive organs,
  kidneys, aorta and pulmonary trunks,
  spleen, musculature as a whole, blood
  volume

Genital type
  Testis, ovary, epididymis, uterine tube,
  prostate, prostatic urethra, seminal
  vesicles

Fig. 2. Main types of postnatal growth of various bodily systems. (*From Harris, J. A.,
Jackson, C. M., Paterson, D. G., and Scammon, R. E. The measurement of man.
Minneapolis: University of Minnesota Press, 1930. P. 193. By permission of the pub-
lishers.*)

of onset and the amount of decline of several capacities. The male para-
thyroid glands, for instance, begin to decrease in size during the fourth
decade; the female, about two decades later (Gilmour and Martin, 1937).
Another example is found in hearing: with advancing years, females show
less loss of hearing for high tones than males (Bunch and Raiford, 1931).

Endocrine Glands. Another important influence on both development
and decline is exerted by the endocrine glands, which produce the various
hormones essential to life as well as to growth. Examples abound in this
field, but one of the clearest appears in cases where the thyroid gland is
underactive during infancy and early childhood. Such underactivity re-
sults in retarded physical, sexual, and intellectual development. A similar
condition in adults produces a changed physical appearance, emotional
apathy, and mental sluggishness. Administration of thyroid extract
quickly restores normality. Recent research has suggested that certain

kinds of hormone treatment in old age may restore several physical and psychological capacities to varying degrees (see Chapter 4).

Influence of Intelligence. Intelligence level may also influence the rate of development and decline of several aspects of behavior. Some years ago, Terman (1925) reported that children with IQ's of 140 or over were on an average from 5 to 12 lb. heavier and from 1 to 3 in. taller than their age norms. At the other extreme, mentally deficient teen-age children whose IQ's were below 70 were reported to be about 30 lb. lighter and, in the case of idiots, about 6 in. shorter than the age norms (Goddard, cited by Paterson, 1930). In the mentally deficient, puberty is also frequently retarded or may fail to appear entirely. While such physical phenomena are correlated with intelligence level, they are not *caused* by extremes of intelligence; rather, some unknown factor (perhaps enzymes or hormones) may be responsible for both physical and mental deviations.

Nevertheless, the direct influence of mental ability appears in several instances. It is reflected in such things as rate of mental growth, age of mental maturity, interests, and social and attitude development. Mental ability can also influence the age of onset and the rate of decline of various capacities. In mentally superior adults, for example (the top 5 per cent of the population), performance on vocabulary tests either shows no decline or actually improves with advancing age; in persons of average ability, decline is slight; in those of inferior ability (bottom 25 per cent of the population), vocabulary scores decrease considerably in old age. Essentially similar results have been obtained for reasoning ability (Raven, 1948).

These are only a few examples of factors which can influence human development and decline. Many more will appear in later chapters.

GENETIC FOUNDATIONS OF BEHAVIOR

Contrary to popular notions, human development does not begin at birth but at the moment of fertilization, when the male sperm unites with the female egg, or ovum, to give rise to a new individual. This is the crucial event of the life span, for at this time certain potentialities and limits are irrevocably fixed. The biological substances present in the sperm and ovum determine whether the new organism will become a human being or one of the lower species; sex is established, and many physical and mental characteristics are delimited in a way which not future growth, development, or learning can alter. Because the possible combinations of various biological factors are infinite, no two individuals will be exact replicas of each other; yet, because of these same hereditary combinations, children will be more like parents, siblings, and other kin than like unrelated individuals. While hereditary factors determine potentialities, however, both prenatal and postnatal environments may advance or retard development.

What are these hereditary factors? How do they operate? The answers to these questions are the keys to the important problem of individual differences as well as similarities.

MECHANISMS OF INHERITANCE

Structure of Cells. First let us briefly consider cell structure. Regardless of their location, all body cells consist of a dense mass of protoplasm, called a *nucleus*, surrounded by a less dense *cytoplasm* (see Fig. 3). From the viewpoint of heredity, the nucleus is the more important, for it contains the hereditary factors known as *chromosomes*. When certain stains are applied to the cell nucleus the chromosomes appear as colored bodies of varying shape and size; under a microscope they may be seen as rodlike, sausage-shaped structures. Strung out along their entire length like beads on a chain are fine particles called *genes*, the true carriers of heredity. Genes are so small that we cannot see them even through high-powered microscopes; we must infer their existence from indirect evidence. Before we say more about genes, let us examine the larger chromosomes a little more closely.

Chromosomes differ in size, shape, number, and gene arrangement from species to species but are alike in members of the same species. There seems to be no relationship between number of chromosomes and position in the phylogenetic scale. The fruit fly, or Drosophila, so frequently studied by geneticists, usually has 4 pairs of chromosomes, for example; the moth, crayfish, and certain protozoa have over 100 pairs; man has 24 pairs.

Reduction of Chromosomes. Every body cell of the human being contains 48 chromosomes, or 24 pairs, one of each pair deri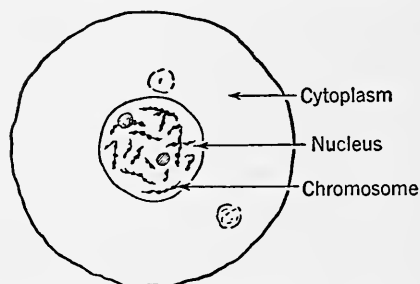ved from the male parent and one from the female. When this is considered in terms of transmission from one generation to the next, it becomes evident that if each parent has 48 chromosomes some mechanism for reducing this number by half must exist if the total is to be kept constant. Such a reduction process is known as germ-cell maturation, or *meiosis*. It takes place in the reproductive organs, or *gonads*—the female ovaries and the male testes. Prior to puberty the cells in the gonads are just like any other body cells, each having 24 pairs of chromosomes. At this time of life the sex cells—the ova and *spermatozoa*, or sperms—are dormant. Before they can function they must mature, and it is during the maturation process that meiosis occurs.

FIG. 3. Structure of a typical cell. (*From Brooks, F. D. Child psychology. Boston: Houghton Mifflin, 1937. P. 20. By permission of the publishers.*)

In the present context, the important thing about meiosis is that separation of the 48 chromosomes into two groups of 24 occurs on a chance basis, so that any combination is possible. An example will clarify this. An immature male sex cell has 48 chromosomes, half inherited from the mother and half from the father. Let us call the 24 inherited from the paternal side "*p*" and the half from the maternal side "*m*." Thus the immature sex cell will contain 24 *p* + 24 *m* chromosomes. As the cell matures, reduction division begins, and the 24 *p* + 24 *m* chromosomes are randomly distributed between two new cells. Since this division is based on chance, one of the resultant cells may contain 4 *p* + 20 *m* chromosomes while the other contains 20 *p* + 4 *m*, or one may receive 17 *p* + 7 *m* while the second receives 7 *p* + 17 *m*.

Because of such chance distribution it is impossible to predict whether a certain mature sex cell will carry a chromosome load derived chiefly from paternal forebears, chiefly from the maternal side of the family, or half from each. Moreover, the sperms are so numerous that it cannot be predicted which particular sperm will eventually fertilize an ovum, for

this also occurs on a chance basis. For these reasons one child may resemble paternal ancestors while another is more like the maternal line. It is unlikely, however, that any two children will be replicas of each other or that any child will be a carbon copy of either parent. Chance distribution thus becomes the basis of both familial resemblances and individual differences. Let us now examine the ovum and the sperm more closely.

The Ovum. The ovum is larger than any other body cell. Besides the chromosome-carrying nucleus it contains a large bulk of cytoplasm and enough yolk to nourish the young embryo until it becomes a parasite. The ovum is nonmotile, depending on the contractions of surrounding tissues for movement. It is estimated that at birth approximately 200,000 immature ova are present in the human ovaries. Roughly 170,000 of these atrophy or degenerate during childhood. At the time of puberty 30,000 remain. Of these, about 400 mature during the reproductive period between puberty and the menopause; the remainder undergo gradual degeneration and are discarded from the body.

The Spermatozoa. The male sperm is much smaller than most other body cells, measuring only 0.05 mm. in diameter. It consists of a "head" containing the 24 chromosomes and a fine whiplike "tail" promoting locomotion. Whereas the ovum must depend on tissue contractions for movement, the sperm is highly motile. Spermatozoa are very numerous; at times as many as 200 million may be present in the seminal fluid of a single ejaculation. It has been estimated that the spermatozoa required to produce the current total population of the world would approximate the bulk of half an aspirin tablet.

Fertilization. The ovary consists of a mass of follicles containing ova. During every menstrual cycle of about 28 days each, one of these follicles swells and ruptures, emitting a mature ovum. It is generally believed that the two ovaries alternate in this process, so that one month the right ovary expels an ovum while the second month the left one takes over the task. Expulsion of the ripe ovum into the Fallopian tube is called *ovulation*. It usually occurs about 15 days after the first day of the menstrual period.

On entering the Fallopian tube, the ovum remains relatively stationary for 3 to 7 days. If no sperm is present, the ovum deteriorates and is expelled from the body. If a sperm is present, it penetrates the membrane of the ovum and the two nuclei merge. The 24 chromosomes carried in the nucleus of the sperm mingle with the 24 already present in the ovum, thereby restoring the chromosome load to 48. It is this fusion of nuclei which constitutes *fertilization*, or conception. As soon as it has occurred, the new organism is known as a *zygote*.

We have already emphasized the chance distribution of chromosomes in both sperm and ovum. Because no two sperms or ova are ever alike it is

not surprising that one child may be small, blond, and blue-eyed while a sibling is tall, dark, and brown-eyed. Only in identical twins whose genetic components are identical do we find close and consistent similarities.

Fraternal and Identical Twins. In the human female, one ovum usually ripens at a particular time, and if it is fertilized one zygote develops. Nevertheless, it may happen that two or even more ova mature simultaneously, and hence, if fertilization occurs, multiple births may follow. Twins who develop from two such separate ova are known as *dizygous*, or *fraternal*, *twins*. Since they result from independent zygotes they are no more alike than other siblings. They may differ in sex, developmental rates, height, eye and hair color, and other characteristics. Fraternal twins occur in approximately 1 out of every 85 births in America.

Twins may be produced in another way, however. After the first mitotic division of a fertilized ovum (see Mitosis, below), the cells may separate and subsequently develop independently, thereby giving rise to two individuals. We do not know why this happens. Since such individuals began as a single zygote they are called *monozygous*, or *identical*, *twins*. They represent roughly one-quarter of all twins born. They are always of the same sex and closely resemble each other in both physical and mental characteristics. Because they share a common heredity, any differences which appear later may be attributed to environment. For this reason investigators have used identical twins as subjects in studies of heredity-environment influences. Such studies will be discussed in later chapters.

Mitosis. Like other organisms, the human being begins as a single cell, yet by the time of birth some 10 lunar months (280 days) later his body contains about 2 billion cells. This astounding increase is achieved through a process called *mitosis*, schematically illustrated in Fig. 4. Unlike meiosis, mitosis is a duplication process in which the chromosome number of each cell remains constant.

When the fertilized ovum is about to divide, the 48 chromosomes shorten and thicken (Fig. 4B). The membrane surrounding the nucleus disappears, and the chromosomes arrange themselves in linear fashion across the cell (Fig. 4C). Soon each chromosome splits lengthwise, thereby achieving duplication. The slender "halves" separate, one complete set of halves migrating toward one pole of the cell while the second set moves off in the opposite direction (Fig. 4D). A new cell wall is then laid down in mid-line, and the chromosomes collect centrally in each of the two new cells to form new nuclei (Fig. 4E). Thus there are two cells, each carrying a complete and identical chromosome load (Fig. 4F).

In the same way, the two cells subdivide to form four, the four to form eight, and so on in geometric progression until the individual achieves the maximum number present in the human adult. As division proceeds, cells begin to differentiate both structurally and functionally, forming bones,
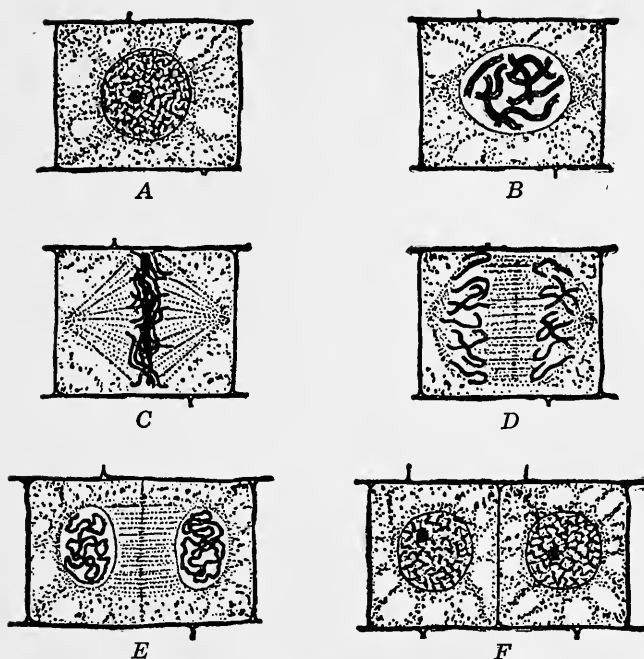
Fig. 4. Diagram of cell division by mitosis. (*From Sinnott, E. W., Dunn, L. C., and Dobzhansky, T. Principles of genetics. (4th Ed.) New York: McGraw-Hill, 1950. P. 155. By permission of the publishers.*)

muscles, and body organs. Through all subsequent stages, however, all cells carry within their nuclei the freight of identical chromosome sets.

Genes

It has already been observed that each chromosome consists of a chain of beadlike particles, called genes. For this reason the study of heredity has been called *genetics*. These genes are the real units of heredity. Each chromosome of a pair carries the same number of genes arranged in similar linear sequence regardless of the fact that one may have come from the paternal and the other from the maternal parent. Accordingly, if we were to place a pair of chromosomes side by side, a certain gene of the first chromosome would be paired with the corresponding gene of the second.

Such paired genes govern various characteristics of the individual. One pair may determine eye color, for example, while others govern hair texture, skin coloring, and other attributes. The two genes of a pair may be quite different, however. One may be the factor for brown eyes while the other promotes blue eyes, or one may be a gene for straight hair while its mate is for curly hair. If the two genes of a pair are identical, they are designated as *homozygous*, or "purebred," for the characteristics gov-

erned; if they differ, they are *heterozygous*, hybrid, or, in common parlance, "mongrel."

Dominance-Recessiveness. Quite frequently an individual is heterozygous for several characteristics. He may, for example, inherit a gene for brown eyes and a gene for blue eyes. What, then, will be his eye color? To answer this we must introduce the concepts of *dominance* and *recessiveness*. For many characteristics, including eye color, one of the paired genes exerts greater influence than the other. The one with the greater influence is called a dominant gene; the other, a recessive. In the case of eye color, the gene for brown is always dominant over the gene for blue. This means that, whenever both genes are present, the gene for brown will suppress the effect of the gene for blue and the individual will be brown-eyed. The recessive gene does not disappear, however. It merely fails to express itself in visible form in this individual. It may be transmitted again to the next generation. Since such transmission is essentially the same for other characteristics more important to us than eye color, let us carry the illustration further.

Geneticists represent dominant genes by capital letters and recessive genes by small letters. Since the gene for brown eyes is invariably dominant over the gene for blue, let us designate the gene for brown B and the gene for blue b. Now, an individual may inherit a dominant gene from each parent and thus have a homozygous dominant combination, BB; he may receive a dominant gene from one parent and a recessive from the other, thereby achieving a heterozygous combination, Bb; or lastly he may inherit recessives from both parents and have a homozygous recessive combination, bb. Since the gene for brown suppresses the effect of the gene for blue, both BB and Bb individuals will be brown-eyed and only the homozygous recessive, bb, will be blue-eyed.

Although both BB and Bb combinations produce brown eyes, it is clear that the genetic components differ. The homozygous BB can transmit only a dominant gene, B, to his offspring. The heterozygous Bb individual, on the other hand, can transmit either a dominant gene, B, or a recessive gene b, to his children. If this idea is followed a little further, it will be seen that all children of the BB individual will be brown-eyed regardless of their mother's eye color. Prediction of eye color of Bb's children becomes more complicated, however. Let us see what happens if he marries a girl who is also heterozygous for eye color. In genetics, the symbol $\male$ is used to represent the male parent and $\female$ to designate the female parent. In our example, both are heterozygous with respect to eye color, thus:

$$\male : B + b$$
$$\female : B + b$$
$$\overline{1\ BB : 2\ Bb : 1\ bb}$$

By simple algebraic multiplication, we find that the chance is 1 out of 4 that any child of these parents will inherit two dominant genes, *BB*; chances are 2 out of 4 that any child will have one dominant and one recessive gene, *Bb*; and the chance is 1 out of 4 that any child will have two recessive genes, *bb*. If we now recall that brown suppresses the effect of blue, it becomes clear that both the 1 *BB* and the 2 *Bb* children will be brown-eyed. We might therefore conclude that the chances are 3 to 4 that children of these heterozygous parents will be brown-eyed, like their parents. Nevertheless, it is important to note that although the odds are against it there is 1 chance in 4 that children will inherit a homozygous recessive gene combination, *bb*, and hence be blue-eyed. Even though no blue eyes appear in this generation, some of the children are likely to carry the gene for blue eyes in heterozygous combination, and this hidden gene may be passed along from one generation to the next to reappear in grandchildren or great-grandchildren who fail to understand it because in their lifetime no one in the family ever had blue eyes.

Accordingly, we see that genes for certain characteristics may express themselves in every generation or may be carried as heterozygous recessives, remaining hidden for many years to reappear several generations later. Examples of dominant genes are numerous—skin and hair coloring and texture, height, etc. Recessive genes underlie such conditions as albinism (absence of pigmentation in skin and hair), juvenile amaurotic idiocy, muscle atrophy, color blindness, and hemophilia. Sometimes a gene may have a recessive effect on one characteristic and a dominant effect on another. In the ordinary house mouse, for instance, one gene is known to have a recessive influence on viability, for all homozygotes die before birth, and a dominant effect on coat color which in the presence of this gene becomes yellow instead of the usual gray.

Eugenics. Eugenicists have long advocated the improvement of the human race by eliminating undesirable genes from the population through various means such as sterilization. The difficulty is easily seen, however. Even though enforced selective mating were possible and legal among human beings, recessive genes might remain hidden for generations only to express themselves unexpectedly a century later. Nature eliminates many of the undesirable characteristics without human intervention, for many such genes are lethal and the carrier dies before sexual maturation. For nonlethal recessive genes, eugenics would appear to offer no simple solution.

Multiple Factors. The task of the geneticist would be relatively elementary if heredity depended on individual genes. In order to clarify principles in this brief discussion, we have oversimplified. Few, if any, human genes act independently. Although in lower animals certain characteristics seem to be determined by single or few genes, most human

characteristics such as eye or hair color, blood type, and body build are determined by a large number of interacting genes. In many instances this is also true of the lower animals. A seemingly simple characteristic such as the eye color of the fruit fly, for example, has been shown to depend on the interaction of about 50 separate genes.

Influence of Environment on Gene Action. Although genes play an important role in determining the characteristics of the individual, their action depends on a constant environment. Should changes occur in either prenatal or postnatal environment, the course of development may be drastically altered. It has been demonstrated, for instance, that fruit flies hatched under conditions of low temperature may develop additional legs, while controls hatched in the usual warm temperatures have a normal number of legs (Jennings, 1930). Another interesting illustration has been provided by Stockard (1909), who found that the larvae of a certain fish which normally had two eyes developed only one eye if subjected to high concentrations of magnesium salts in the sea water in which they lived. Erickson (1944) reported that children whose mothers had German measles during pregnancy were prone to malformations of ears, eyes, and heart. These are only a few of many available examples. Nevertheless, they are sufficient to show that the kind of organism which will develop depends not only on genes but also on the nature of the environment in which the genes exert their influences.

Genes and Enzymes. For many years investigators have wondered just how the genes determine hereditary characteristics. Research has recently begun to point toward the action of genes on the various *enzyme* systems of the body (see Chapter 4 for discussion of the nature of enzymes). Enzymes are catalysts which affect the rate of various chemical reactions in the body but undergo no change themselves.

Most of the work on gene-enzyme relationships began with the studies of Beadle and Tatum (1941), who worked with the common bread mold. It is known that bread mold makes one of its vitamins, thiamin, from two simple compounds and that a specific enzyme is required to accomplish this synthesis. It was demonstrated that this enzyme is produced by a gene which these investigators were able to locate within the chromosome. When the gene was inactivated by X-ray bombardment, the enzyme was also inactivated and the bread mold could no longer make its own thiamin. Similar relationships between a specific gene and a specific enzyme have been found in several other cases in both plants and animals.

Such research led to the view that a 1:1 correspondence exists between genes and enzymes and that many effects of genes are exerted through enzymes produced or catalyzed by the genes. This suggested the hypothesis that genes may be considered as templates or molds of various shapes that serve to stamp out enzymes of a particular kind (Beadle, 1945). For

our purposes, the important thing is to note that the gene can determine the presence or absence of an enzyme as well as its particular nature and thus, through the enzyme system, can affect the rate of metabolic activities of the body and hence behavior.

Enzymes and Behavior. Of late years, accumulating evidence has indicated that absent or malfunctioning enzyme systems influence behavior. For example, in one investigation it was noted that disturbed enzyme
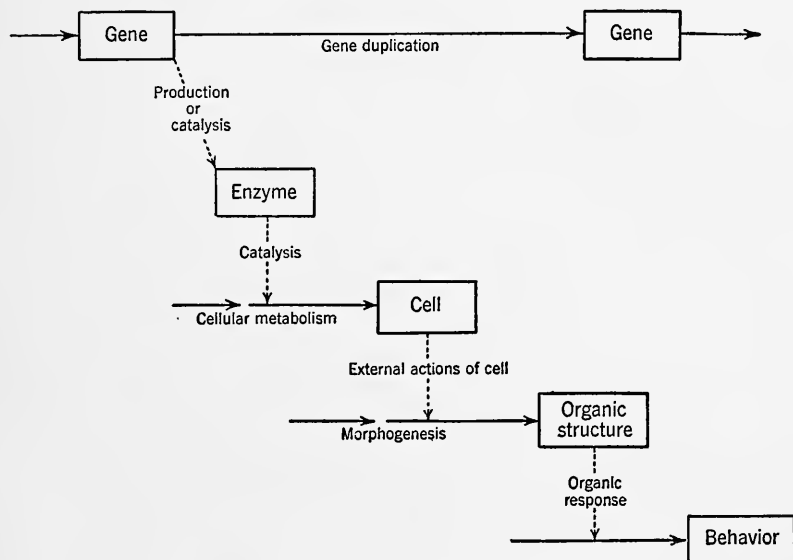

FIG. 5. Diagram illustrating the chain of processes connecting the most immediate effects of a gene with the eventual effect on behavior. (*After Wright. Modified from Sinnott, E. W., Dunn, L. C., and Dobzhansky, T. Principles of genetics. (4th Ed.) New York: McGraw-Hill, 1950. P. 416.*)

functioning resulted in a psychotic condition characterized by fears, delusions, and hallucinations. When normal enzyme action was restored, the symptoms promptly disappeared (see Chapter 4 for a fuller treatment of this topic).

One of the most interesting examples comes from study of a type of mental deficiency known by the elaborate name of *phenylpyruvic oligophrenia*. It is well known that, during the course of normal metabolism, phenylpyruvic acid is produced. With the help of a specific enzyme, this acid is reduced to carbon dioxide and water. However, the necessary enzyme seems to be lacking in a few people (the result of a recessive gene); therefore, the acid remains unoxidized, accumulates in the body, and is eventually eliminated through the urine. It is an interesting fact that people whose urine contains phenylpyruvic acid are invariably feebleminded. This type of mental deficiency is rare in medical history, account-

ing for approximately 0.1 per cent of the feeble-minded population (Haldane, 1942). It is thought that the accumulation of phenylpyruvic acid in the body inhibits one of the enzymes involved in neural activity and therefore lowers the level of neural and hence mental functioning. In our present context, the most important point is that phenylpyruvic oligophrenia is an inherited disease transmitted by a single recessive gene (Jervis, 1939). This indicates the operation of the following chain: gene → enzyme → metabolism → behavior (phenylpyruvic oligophrenia with its physical and mental symptoms).

From the above examples it becomes evident that certain effects of genes on behavior are mediated by enzymes. Figure 5 illustrates various steps in this relationship, from the most immediate effects of genes to their more remote influence on behavior. It is important to note that, although some of the effects of genes may be mediated by enzymes, this is not the only way in which they influence behavior.

SEX DETERMINATION AND RELATED PHENOMENA

An individual's sex is determined at the time of fertilization. Not long after the discovery that chromosomes occurred in pairs, an exception was also found to this general rule, and the exception led to a theory of sex determination.

Human males and females alike have 24 pairs of chromosomes. Of these, 23 pairs are similar in both sexes. Since the two chromosomes comprising each pair are also alike, for convenience we shall call them AA chromosomes. The twenty-fourth pair, however, differs in male and female. It is therefore safe to assume that sex is determined by this last and different pair. In females, the two chromosomes comprising this pair are matched, so we shall call them XX; in males, the two chromosomes differ, and we shall call them XY. As has already been observed, meiosis divides all chromosomes. Accordingly, each female ovum will carry 23 A + X chromosomes; half of the male sperms will carry 23 A + X chromosomes, while the other half will carry 23 A + Y chromosomes. Thus, if the ovum is fertilized by one of the 23 A + X sperms, two X chromosomes will be present in the zygote, and the individual will be female. On the other hand, if a sperm carrying a 23 A + Y chromosome load should happen to fertilize the ovum, the zygote will have an X and a Y chromosome and will therefore be male. Since the probability of one or another sperm fertilizing the ovum depends on chance alone, any child can be said to have a 50 per cent chance of being a girl and an equal chance of becoming a boy. Similarly, roughly one-half of all children will be male and roughly one-half will be female. Figure 6 schematically illustrates sex determination.

Although theoretically we might expect half of the population to be

male and half female, in reality we find approximately 105 males to every 100 females. The reason is not definitely known. We do know that the sperms carrying the 23 A + Y chromosome load are slightly lighter, and it has therefore been argued that they move faster and hence have a
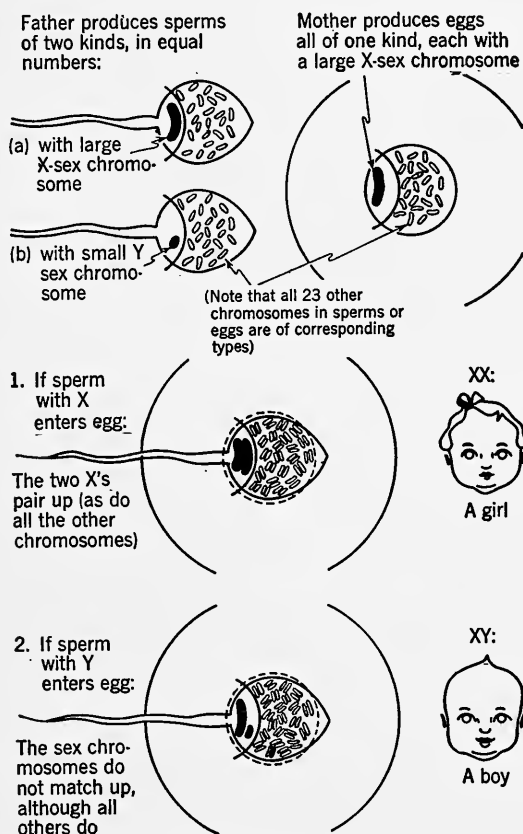

Fig. 6. Determination of sex. (*From Scheinfeld, A. Women and men. New York: Harcourt, Brace, 1944. P. 12. By permission of the publishers.*)

better chance of reaching the ovum first. This has not been proved, however.

Predicting Sex. The sex of an expected child is always a good topic for conversation and wishful thinking. Dozens of superstitions regarding methods of predicting sex are bandied about—for example, "If conception occurs soon after menstruation, the child will be a girl," or, "If the groom goes to bed on his wedding night with his shoes on, his children will be boys." Such superstitions have no basis in fact. Even the old saying that "it's the mother's fault if it's a girl" is untrue, for the mother can contribute only 23 A + X chromosomes to either sons or daughters, while it

is the father's 23 A + X or 23 A + Y chromosomes which determine sex. Which sperm fertilizes the ovum depends entirely on chance.

In recent years attempts have been made to predict sex by X-raying the bones of the fetus on the premise that girls' bones ossify sooner than boys bones. Other attempts have been made by counting fetal heartbeat. However, neither X-ray nor heart-rate tests are very reliable because of the great individual differences even at this early stage of development. Very recently a new technique—the saliva test—has been reported. Its proponents claim almost perfect accuracy in prediction. Whether the claim will be verified remains to be seen.

Sex-linked Traits. Every chromosome contains many genes. This is true also of the sex chromosomes. Both X and Y chromosomes transmit genes which influence other characteristics apart from sex. In view of the peculiarity of transmission of X and Y chromosomes, we may therefore anticipate that certain genes will influence one sex more than the other. Characteristics governed by such genes are called *sex-linked traits*.

Of approximately 20 sex-linked traits known in man, the 2 which have been most extensively studied are color blindness and hemophilia. Color blindness is more frequent in boys, occurring in about 8 per cent of all American males and in 0.5 per cent in American females. It is an eye defect which interferes with color vision and discrimination. It is found in varying degrees ranging from mere "color weakness," in which some difficulty is experienced in distinguishing certain colors, to complete lack of color vision. Red-green color blindness is most common. Hemophilia, often known as bleeder's disease, is another hereditary defect, preventing coagulation of the blood in the presence of air. Even a small cut may result in fatal hemorrhage. This condition is peculiar to males. Genes for both color blindness and hemophilia are sex-linked recessives.

MUTATIONS

Well over a century ago, Lamarck postulated a thesis which subsequently became known as "the inheritance of acquired characteristics." He believed, for example, that an animal such as the giraffe once had a short neck. Because it fed on the leaves of trees, it stretched its neck to reach higher and higher branches, and as a result of such prolonged stretching the neck increased in length. This length increment was inherited by its offspring. As generation succeeded generation, inch by inch was added to neck length until stretching became unnecessary. Thus Lamarck's thesis revolved around the idea that where continuous striving was necessary to adapt to the environment permanent physical changes resulted, and these changes became hereditary.

Although we no longer credit Lamarckian theory, at one time it was

influential, and gave rise to such ideas as that Negroes are black because they lived in tropical climates where increments of "tanning" gradually resulted in dark skin. We know now that this is not the true reason for their dark color. Alterations in body cells may follow environmental changes. Muscles may become highly developed as a result of exercise, for instance, or dietary deficiencies may stunt growth. However, such changes cannot be transmitted to offspring, because they are limited to body cells and do not affect the germ or reproductive cells.

Collapse of Lamarck's thesis left us without a substitute for many years. Darwin's theory of evolution caused scientists to continue their search for a possible method of accounting for phylogenesis, however, and eventually a theory supported by more evidence emerged. This new theory centered around the concept of mutations, defined as "inherited bodily changes brought about by alterations of chromosomes and genes" (Munn, 1938).

Spontaneous Mutations. Unlike the body cells, germ cells are relatively immune to environmental changes. Only rarely do we find "spontaneous" alterations in germ-cell structure resulting in the sudden appearance of new characteristics. These changes, when they do occur, are inherited by the offspring of affected parents. Morgan (1932) and his co-workers observed such spontaneous alterations or mutations in roughly 1 out of every 5,000 to 10,000 fruit flies bred in their laboratory. These mutations resulted in such characteristics as absence of wings or eyes, unusual wing or eye formations, and changes in bristles. Other striking examples of mutants are black sheep, albino rats, and guinea pigs. These mutants breed true; their offspring continue to be like them. It has been claimed that certain human anomalies such as abnormalities of hands and feet, hair and skin color, or head shape are the results of mutations (see Davenport, 1936).

Morgan also observed that X-ray bombardment speeded up mutation frequency about 150 times. The X-ray-induced mutations were of the same kind as those which occurred spontaneously. Recent research has further demonstrated that such factors as temperature and chemicals can increase mutation rates. At the present time this line of research is being actively pursued, and new facts emerge frequently.

Chromosome and Gene Mutations. Both chromosomes and genes may mutate. We get a clue to the method by which chromosome mutations may occur when we recall that during the processes of meiosis and mitosis chromosomes divide, regroup, split, and go through various other maneuvers. It may happen that paired chromosomes fail to separate, that a chromosome breaks and only a part of it goes to the "correct" cell, or that either a chromosome or a gene fails to make an accurate "carbon copy" of itself. We need not concern ourselves with all these possible accidents.

For our purposes it is sufficient to understand that such accidents do happen and that when they occur at these early stages "behind the germ line," the changed characteristics are transmitted to future generations.

Chromosome mutations cannot account for all hereditary changes. More probably we must look to the gene for explanation, and so far we know little about gene mutations. It is thought that they involve chemical changes within the gene itself. When we consider the gene → enzyme → cells → behavior chain mentioned earlier, it is easy to visualize how gene mutations which change the chemical structure of the gene may be reflected in enzymes, metabolism, and finally behavior. The precise relationships, however, can be clarified only by future research.

HEREDITY AND BEHAVIOR

It is generally accepted that such physical characteristics as hair and eye color, body build, and blood type are genetically determined. The problem becomes more difficult when we deal with psychological characteristics such as intelligence, emotionality, or aggressiveness. Because it is difficult to control the many variables in human studies, the best experimental work has been done on animals. Investigators have followed two main methods: (1) selective breeding and (2) observing psychological traits in different strains, breeds, or species. One or two examples of each will be given.

Selective Breeding. Selective breeding, as defined by Hall (1951), "consists of mating animals that display the desired traits and of selecting for breeding from among their offspring those that express the trait. If the trait is regulated by heredity, continued selection for a number of generations in a uniform environment will result in a strain that breeds more or less true for the character under study."

Learning Ability. The classic experiment in this field is Tryon's (1940, 1942). Tryon describes his procedure as follows:

An experiment was begun in 1927 that had as its purpose the establishment by selective breeding of a pure line of maze-bright and a pure line of maze-dull rats. Each animal was run nineteen trials through a seventeen-blind T maze. His score was the total number of entrances into blind alleys. The breeding schedule consisted in mating together the brightest rat within each of the brightest litters, the dullest within each of the dullest. Rigorous environmental controls were effected (1) by instituting standard procedure of animal care and breeding, (2) by using an automatic mechanical device for delivering the animals into the maze without handling, and (3) by employing an electrical recorder for the scoring of each rat's maze run. These controls have remained constant for eleven years. Selective breeding has continued for eighteen generations [1940, p. 112].

Tryon's description indicates the difficulties encountered in such a

study as well as the time involved and the actual techniques used. He began with 142 unselected rats. His results for the initial test of maze-learning ability and for those of eight successive generations are shown in Fig. 7. The scores of the original unselected rats approximate a rough normal-curve distribution. Greater scattering appears in the scores of the second generation; by the seventh and eighth generations they form two
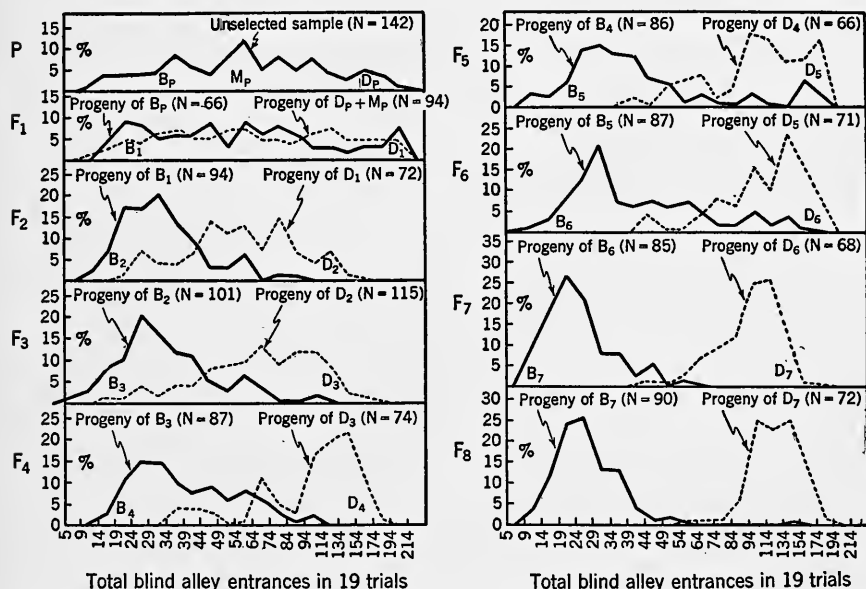

Total blind alley entrances in 19 trials   Total blind alley entrances in 19 trials

FIG. 7. Effects of selective breeding on individual differences in learning ability of rats. (*After Tryon, R. C. Individual differences. In F. A. Moss (Ed.), Comparative psychology. New York: Prentice-Hall, 1942. Pp. 344 and 345. By permission of the publishers.*)

distinct distributions with scarcely any overlap. Thus the bright rats breed bright rats, and the dull ones breed dull offspring. No further changes were observed from the eighth to the eighteenth generations. The experiment indicates that maze-learning ability is inherited.

Activity. A similar method of selective breeding has been used to appraise the role of heredity in voluntary activity of rats (Rundquist, 1933). The animals were placed in a revolving drum, and the number of revolutions of the drum served as a criterion of high or low activity level. Highly active rats were paired with others showing high activity, while low-activity animals were paired with similar ones for several generations. Like Tryon, this investigator was able to establish a strain which bred true for high activity rate and another which bred true for low activity level.

Emotionality. A third investigator succeeded in developing a strain of

rats with high emotionality and a strain with low emotionality (Hall, 1938). He states: "The consistency within some litters of the emotional and non-emotional strains may be illustrated by two examples of parent-child resemblances. Two emotional F_9 rats with scores of 10 and 12 had a litter whose nine scores were 12, 12, 12, 12, 12, 12, 11, 11 and 10. Two non-emotional F_9 rats with scores of 0 and 0 had a litter of six whose scores were 0, 0, 0, 0, 1 and 1."

While these three experiments indicate that maze-learning ability, voluntary activity, and emotionality all have large hereditary components, it should be remembered that these rats were reared and tested in constant environments. We cannot predict the role of heredity when environmental variables are not controlled. This will become clear in later chapters when the nature-nurture experiments performed with children are discussed.

Study of Different Strains. A strain may be considered as "a group of individuals of a species that have a common lineage resulting from either natural or artificial selection and inbreeding" (Hall, 1951). Over a number of generations, close inbreeding results in a pure strain which breeds true for inherited traits unless mutations occur. Thus by a pure strain we mean homozygous individuals with *BB* or *bb* gene combinations as opposed to the heterozygous *Bb* of mongrel subjects. As we have observed, such homozygous individuals will show the effects of either dominant or recessive genes regardless of whether they are beneficial or deleterious characteristics.

Wildness and Tameness. Several investigators have applied this knowledge to observation of such temperamental traits as wildness or tameness of certain animals (Yerkes, 1913; Stone, 1932; Dawson, 1932; among others). It was found that wild strains bred true for wildness and tame strains for tameness in both rats and mice. In one study a number of wild gray Norway rats were captured and their offspring reared in cages similar to those used to rear albino rats (Farris and Yeakel, 1945). Both the wild and tame rats bred true; the descendants of the wild gray Norway rats remained wild; offspring of the albinos remained tame. Since the two strains bred true for wildness and tameness, it is clear that the difference has a genetic basis.

Aggressiveness. Of recent years many psychologists and psychiatrists have supported what is known as the frustration-aggression hypothesis. A child who is thwarted in his activities, for example, allegedly responds aggressively by striking his mother, kicking the furniture, breaking into a temper tantrum, or other such behavior. The social scientists especially are prone to believe that men fight because they have been brought up in a tradition favoring war and not because of inherent pugnacity. An inter-

esting experiment pertinent to this view has been reported by Hall and Klein (1942), who compared two strains of rats using tests of aggressiveness. One strain had been selectively bred to develop fearfulness (emotionality) and the other to develop fearlessness (nonemotionality). Two rats were placed together in a cage for 5-min. intervals, and aggressive behavior was noted and scored carefully. To avoid any "clash of incompatible personalities," each rat was at one time or another matched with every other rat of his own strain. The resulting scores are extremely interesting. The 15 rats of the fearless strain initiated 326 attacks as compared with 68 begun by the fearful rats. The severity of attacks by the fearless animals was roughly twice as great as the severity of attacks initiated by the fearful rats.

Further support for this finding that aggressiveness may have a genetic basis is given in a study by Ginsburg and Allee (1942). These investigators studied the fighting behavior of three strains of mice, pairing each mouse with every other mouse. Of the three strains—black, agouti, and albino— the black mice won the greatest number of fights, the agoutis came second, and the albinos usually lost. To eliminate the possibility that rearing influenced fighting ability, the investigators next split a litter of blacks and a litter of albinos so that some blacks were reared by an albino foster mother and some albinos in a black foster home. On testing the foster children, it was found that the blacks continued to be superior in fighting ability regardless of where they had been reared, while the albinos remained inferior.

Although these few studies do not prove by any means that the Germans are "naturally warlike," the Scottish "naturally thrifty," or the Irish "naturally witty," they do suggest that more experimental evidence is needed before we can safely attribute such characteristics as aggressiveness to environmental influence alone (see Hall, 1951, for further discussion).

Human Studies. Investigators of the heredity-environment problem, often called the nature-nurture controversy, have compared identical twins with fraternal twins or other siblings. Since such studies are scattered throughout the text in appropriate chapters, little need be said about them at this point. All such studies are based on the premise that identical twins have similar hereditary components and that any differences which emerge with advancing age are therefore due to prenatal and/or postnatal environments. To approach this from another angle, it might be said that the genetic components of identical twins are similar, while those of fraternal twins or siblings differ; accordingly, a comparison of certain measurements for identical twins, fraternal twins, and siblings by means of correlation techniques would yield higher correlation coeffi-

cients for the identical twins than for the fraternal twins or siblings. This has proved to be true. In the field of intelligence tests, for example, we find a hierarchy like this:

Identical twins reared together............ $r = +.85$
Identical twins reared apart............... $r = +.70$
Fraternal twins reared together.......... $r = +.64$
Siblings reared together................. $r = +.50$
Father-child or mother-child............. $r = +.50$

Although these correlation coefficients are sufficiently high to point to some hereditary components in intelligence, the difference between identi-
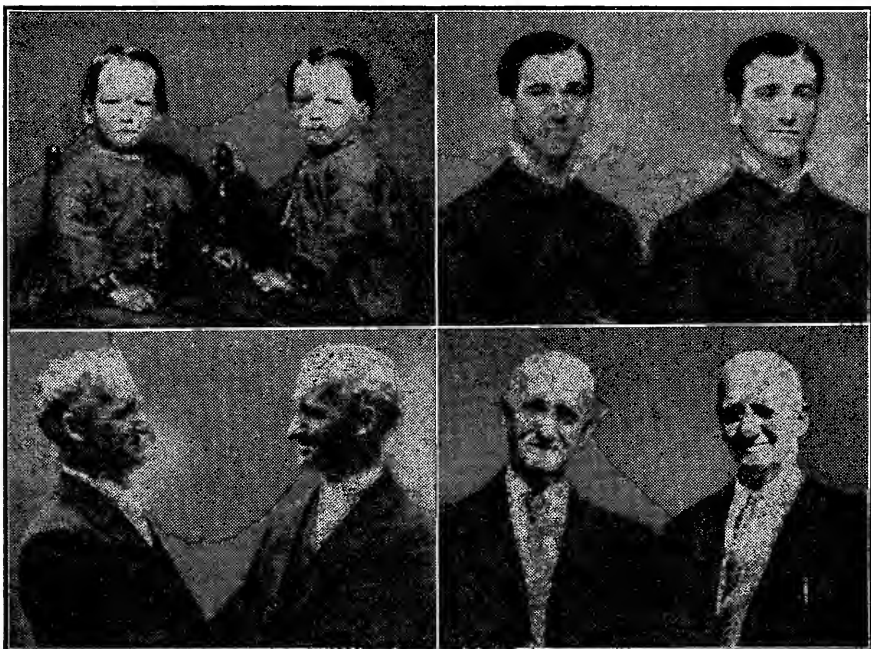

Fig. 8. Life-long similarities of the D identical twins at ages 5, 20, 55, and 86. (*From Kallmann, F. J., and Sander, G. Twin studies on senescence. Amer. J. Psychiat., 1949, 106, 33. By permission of the authors and the American Psychiatric Association.*)

cal twins reared together and apart also points to the influence of environment. The various factors which complicate interpretation of such correlation studies will be discussed later. Here the student is merely cautioned not to jump to conclusions, for there *are* complicating factors. So far as we know at present there is no "gene for intelligence," although it has been postulated by some investigators. Many prefer to think that what we call intelligence depends on the interaction of many gene-sponsored processes—sensory, neural, and glandular—about which we are still in the dark.

Evidence is available to show that, whatever their origins, the similarities of identical twins tend to persist throughout life (Kallmann and Sander, 1949). Similarities include such things as loss of strength in old age; graying and thinning of hair; configuration of baldness; type and extent of eye, ear, and dental defects; and intelligence level as gauged by present-day tests. Figure 8 shows the striking similarities between identical twins at the ages of 5, 20, 55, and 86 years. These twins remain as indistinguishable in old age as they were during childhood and maturity. Striking physical likenesses persist despite the varied influences of city vs. country or professional vs. laboring-class surroundings. Kallmann and Sander cite many cases in which the same ailments occurred at approximately the same time of life in both twins; in which twin sisters both developed essentially similar senile psychoses despite significant differences in social and mental histories; and in which twins both became blind or deaf during the same month, sustained massive cerebral hemorrhages on the same day, and finally died within a few days of each other.

NEURAL DEVELOPMENT

Now that we have learned something about the genetic foundations of behavior, let us go on to a discussion of the nervous system, the great integrator which coordinates the various body responses into one unified whole. Perhaps no structural system is so important to behavior, for through its extensive connections with all parts of the body the nervous system is able to integrate various excitations coming from the receptors and to direct them to appropriate response organs, such as the muscles and glands.

This chapter first traces the phylogenetic development of the nervous system, showing how it gradually becomes more and more complicated in its interconnections and finally reaches a climax in the cerebral cortex of man. This culmination of neural development is reflected in man's ability to recall past experiences, to reason, to plan ahead, and to communicate his thoughts through speech. The second part of the chapter deals with ontogenetic changes, tracing the course of neural development and subsequent decline from the prenatal period to senescence. Such a study of ontogenetic changes is helpful to an understanding of the growth and later decline of such psychological processes as learning, memory, intelligence, and emotions.

PHYLOGENETIC DEVELOPMENT OF THE NERVOUS SYSTEM

Invertebrates. The nervous system consists of specialized conduction lines whose main function is to transmit the effects of stimulation from the receptors to the effectors, or response organs. In the simple one-celled *protozoa*, the best example of which is the amoeba, these effects are mediated by the entire body and no one part of the organism is specialized for either the reception or transmission of stimuli or for effecting any response. However, in the *porifera*, or sponges—the simplest of the multicellular organisms—an advance may be seen in the formation of muscle cells which will contract when stimulated directly. This is shown in Fig. 9*A*. No nervous system is present at this early stage.

Development of Nerve Net. Coelenterates such as the hydra, medusa, and

jellyfish show a further advance, for here certain cells differentiate to become specialized as receptors of external stimuli. These receptor cells receive stimuli and transmit them directly to the underlying muscles by means of elongated branches, called *neurites* (Fig. 9*B*). In certain coelenterates an even more important advance may be seen in the extensive network of nerve fibers which link receptor to effector cells. Since the fibers of this system appear to be fused together in the form of a net, this type is referred to as the *nerve-net* system (Fig. 9*C*). With such a neural arrangement, stimulation of one receptor cell spreads in all directions throughout the net, thus influencing a great many effectors and producing
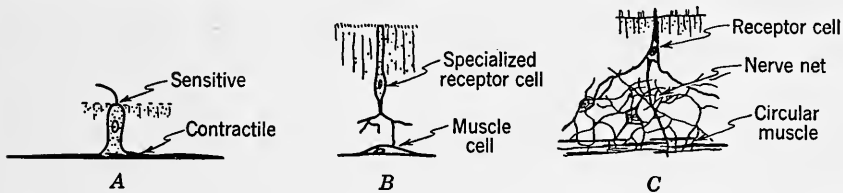

FIG. 9. Stages in the evolution of the receptor-connector-effector system. (*A*) Stage at which a single cell performs the functions of both reception and contraction (*e.g.*, cell in sponge). (*B*) Stage at which a specialized receptor cell and a specialized contractile cell are directly connected (*e.g.*, in tentacle of hydra). (*C*) Stage at which specialized conduction tissue intervenes (*e.g.*, bell of medusa). (*After Parker and Hertwig. From Maier, N. R. F., and Schneirla, T. C. Principles of animal psychology. New York: McGraw-Hill, 1935. P. 43. By permission of the publishers.*)

a generalized response. Although the nerve net functions to bring together various parts of the body, its conduction is diffuse and not channelized through specific pathways as in the "synaptic nervous system" of higher forms.

Development of Axial Arrangement. Following the development of the nerve net, two major steps have occurred in neural evolution. First, the nerve net gradually disappeared to be replaced by structurally separate units, called *neurons*, capable of acting independently of each other. This development made it possible to elicit localized responses to localized stimuli, for example, the blinking of an eyelid following a puff of air or the withdrawal of a finger from a candle flame. The second major step was the gathering of neural fibers into one part of the body. Most important of these neural assemblings is the *axial arrangement*, in which the nerve fibers are strung out throughout the length of the body from head to tail. Such an axial arrangement is found in all higher organisms. The rudiments of an axial arrangement, seen in *flatworms*, is illustrated in Fig. 10*A*. Here two longitudinal nerve strands run through the length of the body to terminate in two large clusters of nerve cells, called *ganglia*, in the head region. These two head, or cephalic, ganglia are the precursors of the vertebrate brain.

Appearance of Reflex Arc. In *annelids* such as the earthworm the nervous system is considerably more organized. The two long nerve strands give place to a chain of paired ganglia extending throughout the length of the organism, each pair serving a segment of the body. The result is the long ladderlike arrangement shown in Fig. 10*B*. Each ganglion is connected with the skin and muscles of its particular body segment by two neurons, a *sensory* neuron which sends impulses from the periphery into the ganglion and a *motor* neuron sending impulses out from the ganglion
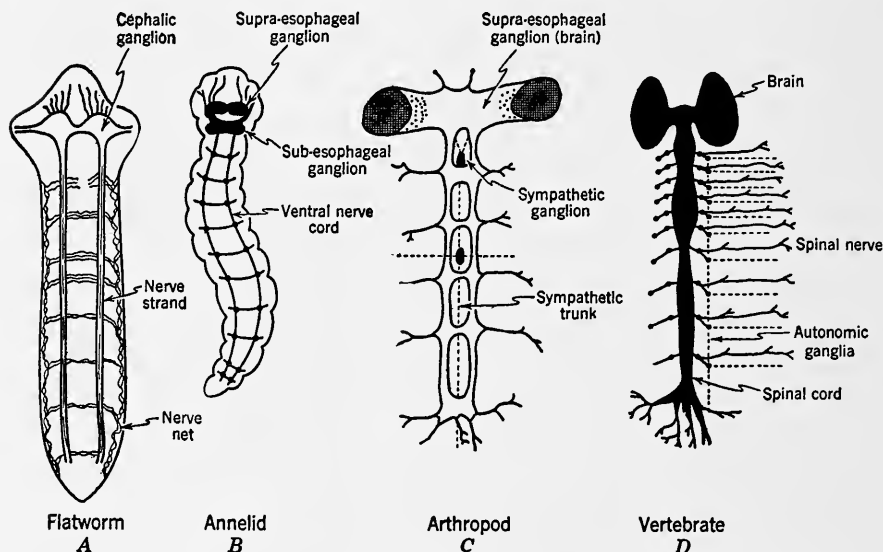

Fig. 10. Diagrams of the nervous system of the flatworm, annelid, arthropod, and vertebrate. The sympathetic nervous system is indicated by dotted lines.

to the peripheral structures. Linking the two neurons in each ganglion is a third *association*, or connector, nerve fiber. Thus in the earthworm are found all the essentials of a reflex arc.

Through these neurons, each ganglion can control movements of its body segment. Furthermore, through a system of association fibers, ganglia serving each segment are interconnected so that movements in one part of the body can be brought into line with movements of other parts. Development of the large head ganglia, which receive impulses from the lower parts and in turn relay impulses to lower segments, provides a mechanism for integrating movements of the organism as a whole. According to Herrick (1924), the nervous system of the earthworm is a rough pattern for that found in vertebrates.

As we ascend the phylogenetic scale from the annelids, we note that paired ganglia come closer and closer together until, in such *arthropods* as the insects, a partial fusion down the central axis of the body occurs. Simi-

larly, in the head region, a number of ganglia fuse to become one large cephalic ganglion, or "brain." This is shown in Fig. 10*C*. Such a "brain" superimposes a certain coordination over various specific reactions; if it is destroyed, serious impairment in both speed and direction of locomotion follows.

Vertebrates. As we go from the highest invertebrates to the vertebrates, we find the segmented, ladderlike arrangement, through a process of fusion, replaced by a nonsegmented, continuous tube called a *spinal cord* (Fig. 10*D*). The posterior part of this cord undergoes relatively little further development. Its sole function is to conduct impulses upward or downward to and from the brain and to act as a center for reflex behavior. The anterior part of the cord changes considerably, however, enlarging and subdividing to form the various components of the brain. The grosser aspects of evolutionary changes of the brain are represented in Fig. 11.

Ascending from fishes through to mammals, the size and complexity of the brain gradually increases. The structure which evidences greatest increase in size is the *cerebral cortex*. This is particularly noticeable in mammals. Below mammals, most of the cortex is concerned with sensory and motor functions. Ascending the mammalian scale, however, there is a gradual increase in the amount of cerebral cortex not given over to sensorimotor activities. This area is known as the *association cortex*. In rodents, approximately 10 per cent of the entire cortex is not dominated by sensorimotor functions; in the cat, roughly 30 per cent; in the monkey, 60 per cent; and, finally, in man, 85 per cent. This is important because it means that man has considerably more cortical tissue free of sensory and motor tasks which can accordingly mediate
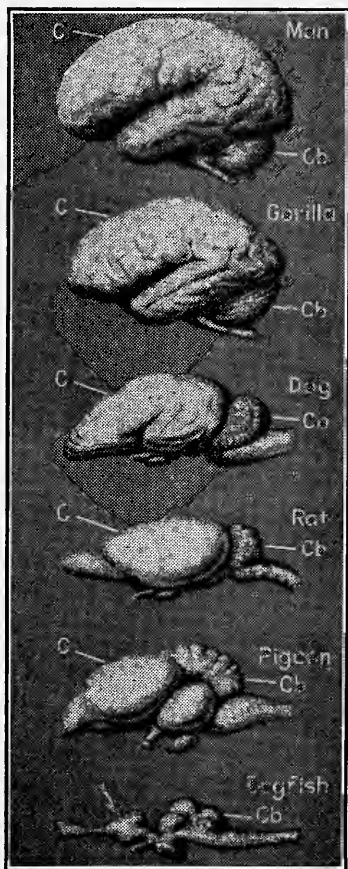

FIG. 11. Evolution of the vertebrate brain. All the brains are drawn to the same length to show detail in the smaller ones. *C* is the cerebrum and *Cb* the cerebellum. Since the dogfish has no cerebrum, an arrow indicates comparable structures. The protruding organ in the extreme left of the lower brains is the smell brain. (*From Munn, N. L. Psychology. Boston: Houghton Mifflin,* 1951. *P.* 49. *By permission of the publishers.*)

such higher psychological processes as learning, thinking, and reasoning. Enlargement of the association cortex is achieved partly by growth in size of the brain and partly by a progressive increase in the amount of infolding of the cerebral cortex (see Fig. 11).

HUMAN NERVOUS SYSTEM

For purposes of discussion, the human nervous system may be divided into two parts: (1) the *central nervous system*, consisting of brain and spinal cord, and (2) the *peripheral nervous system*, comprised of nerves which branch out from the central system. Before discussing these divisions, let us examine some of the microscopic aspects, for the nervous system is so complex that only by inspecting its elements can we hope to understand the functions of the whole.

Components of the Nervous System

The nervous system is made up of billions of highly irritable conductile units known as *neurons*, linked together in various ways to form a complex network of conduction pathways. Scattered among the nerve cells are great numbers of nonconducting, supporting structures called *neuroglia*, or *glial cells*, which give firmness to the neural network. Neurons show considerable variation in size and appearance in different parts of the nervous system. However, all have cell bodies which form the gray matter and branched extensions, or nerve fibers, which constitute the white matter.

Dendrite
Nissl substance
Nucleus and nucleolus
Neuroglial cell
Axon
Myelin sheath
Neuroglial cell
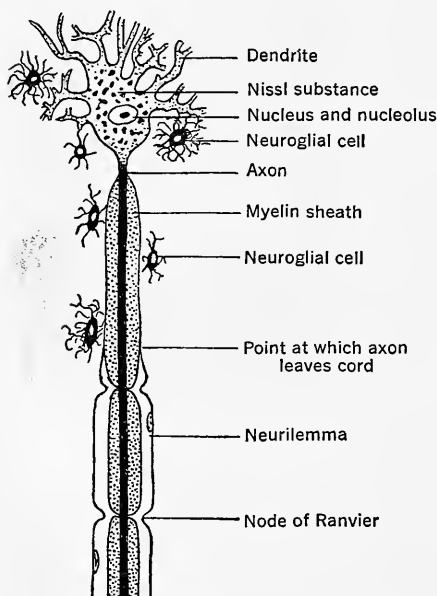Point at which axon leaves cord
Neurilemma
Node of Ranvier

FIG. 12. Diagram of a neuron. The axon is drawn out of proportion so as to illustrate its covering sheaths. (*From Gardner, E. Fundamentals of neurology. Philadelphia: Saunders, 1952. By permission of the publishers.*)

Structure of Neurons. All neurons have a cell body, an axon, and a dendrite (see Fig. 12). As in the case of other cells, the cell body of the neuron consists of cytoplasm. Through the use of various stains, a number of different structures can be distinguished within this cytoplasm. The largest is the *nucleus*, a white, spherical-shaped body. Streaming through

the cytoplasm are many fine, threadlike processes called *neurofibrils*, which form an extensive network within the cell body but straighten out as they reach the periphery, so that in the axons and dendrites they almost parallel each other. Also scattered throughout the cell body are bloblike masses which, under appropriate stains, appear striped, giving the cell a tigroid appearance. This is the *Nissl substance*. Whenever a cell is injured or fatigued, the Nissl substance undergoes extensive disintegration, or *chromatolysis*. There are also other structures within the cell body, but they need not concern us here.

Dendrites and Axons. Dendrites are the receiving end of the neuron. They conduct impulses toward the cell body and, as might be expected, are most numerous in regions easily excited by environmental stimuli. Several dendrites generally arise from one cell body. Axons, on the other hand, carry impulses away from the cell body. Usually only one axon leaves each cell, but there may be a number of side branches, or *collateral fibers*, given off near the cell body at right angles to the main axon.

Myelin Sheath. Some distance from the cell body, many of the nerve fibers become enclosed in a sheath of whitish, fatty material called the *myelin sheath* (see Fig. 12). It is this sheath which lends its white appearance to the nerves and accounts for the term "white matter." Not all fibers composing the various conducting pathways do receive their myelin sheaths at the same time but vary from the third fetal month to some years after birth. The time of myelinization is important, because it is believed that commencement of function coincides with myelinization. This will presently be discussed further.

Neuron Chains. So far, we have been concerned with the neuron per se. The nervous system, however, is made up of a great many neurons linked together in various ways to form intricate conducting pathways. These neurons are so arranged that the axon of one terminates on the cell body or dendrite of another in a junction called a *synapse*.

The simplest functional arrangement of the neuron is the *reflex arc*. In its most elementary form it consists of two neurons synapsing in the central nervous system (Fig. 13). The sensory, or *afferent*, neuron receives the stimulus and transmits it to the central nervous system where the motor, or *efferent*, neuron picks it up and relays it to muscles and glands. Two-neuron arcs are rare in the higher mammals, however. Nearly all arcs include a third neuron interpolated between the afferent and efferent fibers and lying entirely within the central system. This interposed neuron has been variously called the *connector*, *intercalated*, or *association* neuron (Fig. 13). In most human reflex arcs there are not one but many connector neurons. It is these central neurons which are responsible for the complexity of human behavior.

The reflex-arc organization is only one of the many ways in which neu-

rons may be arranged. Another of the more important is the *recurrent nervous circuit*, in which fibers are so linked that impulses set up in one neuron eventually find their way back to the same neuron. These circuits play a role in various activities ranging from simple reflexes to complex psychological processes.
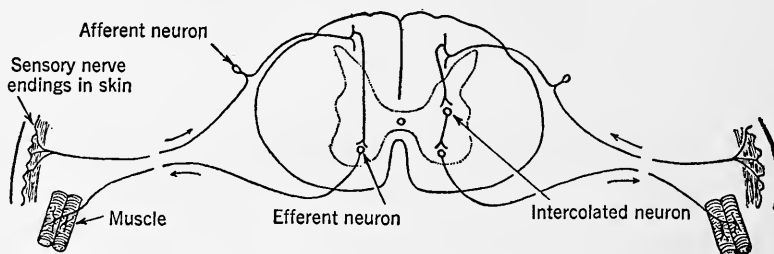

Fig. 13. Diagrammatic representation of simple spinal reflex arcs. The left half of the diagram shows a two-neuron reflex arc, the right half shows a three-neuron arc. Arrows indicate direction of conduction. (*From Kuntz, A.   A textbook of neuroanatomy. Philadelphia: Lea & Febiger, 1950. P. 172. By permission of the publishers.*)

Central Nervous System

Now that we have scanned the characteristics of individual neurons and the assembling of neurons into various functional patterns, let us look at some of the grosser anatomical and functional aspects of the central nervous system.

As may be seen in Fig. 14, the central system is well protected by a thick skull and a long chain of vertebrae. Within the skull, the large cranial cavity, with its capacity of around 1,400 cc. in adult man, is nearly filled by a brain weighing from 2½ to 3 lb. Brain size and weight are functions of the age, sex, and weight of the individual. In addition to the protection afforded by the skull, the brain is also guarded by three fibrous coverings, or *meninges*, known as the *dura mater*, *arachnoid*, and *pia mater*. These meninges are of psychological importance. Bacterial or virus infection may produce an inflammation known as *meningitis*, which is accompanied by intellectual impairment and/or personality changes that tend to be long-lasting and difficult to treat.

As has already been mentioned, the central nervous system consists of the brain and spinal cord. The brain itself may be subdivided into several parts. Discussion of a few subdivisions will contribute to an understanding of development and later-age changes. Let us begin at the top of the brain and work downward.

Cerebral Hemispheres. An aerial view of the brain would show that it is incompletely divided by a longitudinal fissure into two symmetrical halves, the right and left *cerebral hemispheres*, which together make up the *cerebrum*. These hemispheres consist of a layer of gray matter called

the *cortex* and an underlying mass of white matter made up of millions of nerve fibers.

There are many kinds of nerve fibers—short and long, branched and unbranched. On functional grounds they are usually divided into three kinds: association, commissural, and projection fibers. *Association fibers* serve to connect different cortical areas within a hemisphere. *Commissural fibers* pass from one hemisphere to the other, joining different cortical areas of the two halves. *Projection fibers* are of two kinds, efferent and
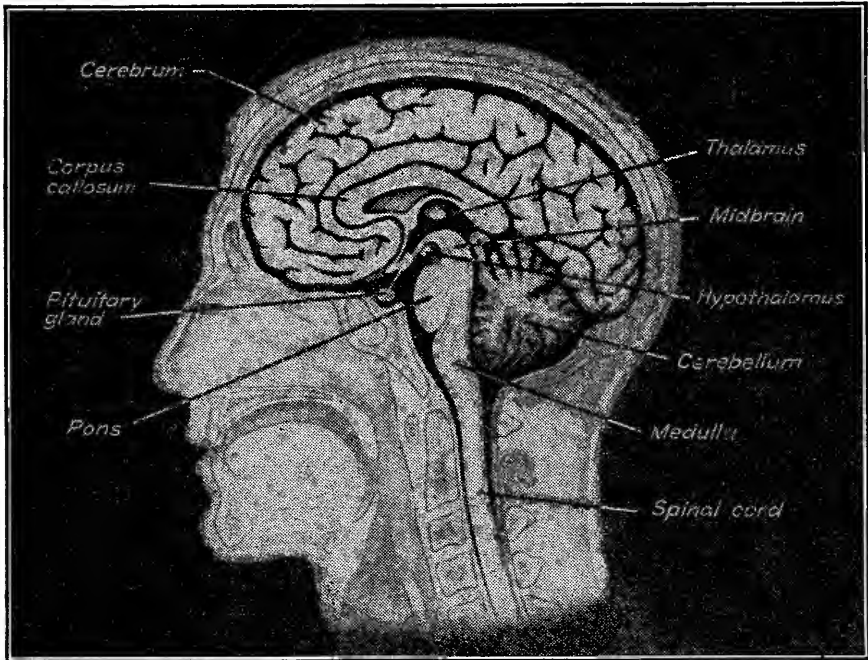

Fig. 14. Cross section of the human brain. (*From Munn, N. L. Psychology. Boston: Houghton Mifflin, 1951. P. 56. By permission of the publishers.*)

afferent. The efferent fibers originate in the cerebral cortex and course downward to various subcortical structures and to the spinal cord, while the afferent fibers relay impulses upward from the subcortical centers—chiefly the thalamus—into cortical areas. Through these three types of fibers, the cerebral hemispheres and lower neural centers are so well interconnected that they can readily function as a unit.

The cerebral cortex has numerous infoldings, or convolutions, which give the brain surface an appearance much like that of a walnut. The elevations are called *gyri* and the depressions *sulci*, while the very deep sulci are known as *fissures*. These sulci and gyri are often used as landmarks or boundaries for various parts of the brain. Perhaps the most

important landmarks are (1) the *central fissure*, which divides each hemisphere into a front and a back half, and (2) the *lateral fissure*, located in the side of each hemisphere (see Fig. 15).

In addition to locating cortical areas by reference to sulci and gyri, a number of systems have been devised for locating them numerically. Many investigators have observed that the cortex is not uniform throughout and that certain areas have cellular features which distinguish them from their neighbors. It has also been observed that these differences are
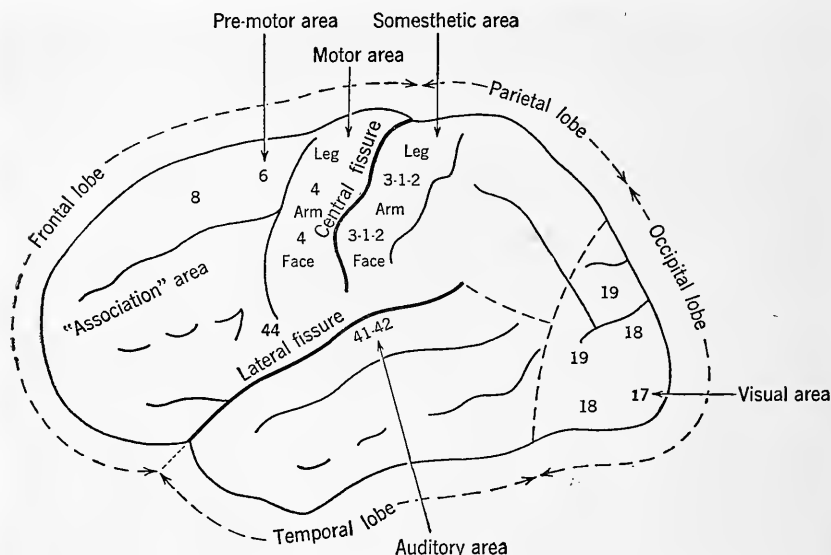

FIG. 15. Schematic drawing of the lateral surface of the left cerebral hemisphere, showing location of the sensorimotor areas and of some Brodmann regions.

related in some degree at least to diversity of function. As new areas were discovered, they were assigned numbers or numbers plus letters. One of the most widely known of such numerical systems is that of *Brodmann*. This system, illustrated in Fig. 15, will be used throughout this text.

Frontal Lobe. Using as a guide the three major landmarks—the longitudinal, central, and lateral fissures—the cerebral cortex can be divided into four pairs of lobes: the *frontal, parietal, occipital,* and *temporal lobes,* clearly shown in Fig. 15.

As might well be anticipated, the frontal lobe lies in the fore part of the brain, anterior to the central fissure. This lobe is very important in connection with physical and motor development, for the brain strip lying immediately in front of the central fissure—known as the *precentral gyrus*—is the center for voluntary movements of all parts of the body. It is usually referred to as the *motor area,* or Brodmann area 4. The cells of

this motor cortex give rise to projection fibers which collectively form the important neural pathway called the *pyramidal*, or *corticospinal*, *tract*. This pathway descends through the substance of the brain, crossing over at the level of the medulla (in some cases lower), so that one side of the body is controlled by the motor cortex of the opposite side of the brain. Destruction of the left motor area, for example, will produce paralysis of the muscles of the right side of the body.

Some interesting things have been found as a result of electrostimulation studies of the motor cortex. It has been demonstrated, for instance, that different regions of this small brain strip control different body parts. If we begin at the top of area 4 and stimulate downward, parts of the body will move in the following order: foot, hip, trunk, arm, fingers, face, and tongue. This sequence is noted in Fig. 15.

Just in front of the motor cortex is area 6, the *premotor area*. Stimulation of this region will elicit body movements of a grosser and more complex nature than those controlled by area 4. It is generally believed that area 6 exerts a controlling influence over the motor cortex, perhaps synthesizing the discrete movements of area 4 into more complex patterns.

The entire cerebral cortex in front of area 6 is often referred to as the frontal "association," or "silent," areas. Since neither sensory nor motor functions have been demonstrated in any part of this region except area 8 (eye movements), people have believed from time to time that various psychological processes such as reasoning, memory, and intelligence are localized here. Investigators differ on this important problem, however, the sole point of agreement being that if lesions involve *Broca's area* (*i.e.*, area 44) disruptions in the expressive side of speech will occur. In concluding a review article on functions of the frontal lobes, Hebb (1945) pretty well summarizes our state of knowledge on this subject: "No one has proved that a single form of normal behavior exclusive of speech is dependent on this part of the brain or that a clean surgical removal of both frontal lobes has any effect on behavior . . . . The loss must, presumably, have some effect but it is hard to demonstrate and its nature is not yet clear."

Parietal Lobe. Behind the central fissure and just above the lateral fissure lies the parietal lobe. In our present context, the most interesting part of this lobe is the *postcentral gyrus*, otherwise known as areas 3, 1, and 2. This is the *somesthetic*, or body-sensitivity, area. It should be remembered later as we study sensory functions (see Chapter 8), for impulses reaching areas 3, 1, and 2 form the basis of our experiences of touch, temperature, and muscular movement as well as of taste. Different parts of the body are represented here in approximately the same order as described for area 4 (for comparisons see Fig. 15). Research has demonstrated that the base of the postcentral gyrus not only performs a somesthetic

function (face-mouth) but also governs our ability to taste (Börnstein, 1940).

Occipital Lobe. The occipital lobe occupies the small triangular area in the posterior end of the brain. This relatively small lobe is concerned with visual functions (see Chapter 7). Neural impulses originating in the eye are transmitted to the extremity of this pole, known as area 17. Just as the various body parts are represented in orderly fashion on the pre- and postcentral gyri, so the various parts of the retina project to the occipital cortex. As yet, little is known of the functions of areas 18 and 19, but they are believed to serve a visual-association function.

Temporal Lobe. Below the lateral fissure is a long, tongue-shaped structure consisting of three gyri running parallel to the fissure and to each other. This is the temporal lobe. Most important to our study is the gyrus bordering on the lateral fissure, for in the middle of it are areas 41 and 42, the terminal points for auditory nerve fibers originating in the cochlea of the ear (see Chapter 7). Electrical stimulation of this region produces noises variously described as "buzzing," "humming," "knocking," etc. Such "sounds" may be continuous or intermittent, loud or soft, and may be "heard" in only one or in both ears. Clinical reports indicate that destruction of the auditory cortex of one side produces very little hearing loss; destruction in both hemispheres, however, results in a considerable degree of deafness.

Other Structures at This Brain Level. In addition to the four lobes just discussed, there are three other structures at this brain level. First of these are the *olfactory bulbs and tracts,* located in the front part of the cranial cavity and connected with the undersurface of the brain. These structures form what is known as the "smell" brain. Secondly, there are the *lateral ventricles,* two pockets located within the cerebral hemispheres. Both of these are filled with cerebrospinal fluid. Thirdly, there are the *basal ganglia,* four masses of gray matter situated for the most part below the cortex but above the thalamus. These structures are halfway stations connecting the premotor area with the cerebellum and spinal cord, forming a system of neural pathways important to the coordination of movements. We shall say more about these presently.

Lower Brain Structures. While the conscious and thinking activities are centered in the cerebral hemispheres, there are many so-called "lower" structures equally important to behavior. Thus, the thalamus relays impulses to and from the cortex, the hypothalamus is essential to vegetative functions and plays a major role in emotional behavior, the cerebellum serves as a timing device for motor activities, and the medulla controls heartbeat and therefore life itself. Disregarding the specific technical classifications of these centers, we shall mention only those es-

sential to our study at this point, for they are all "lower centers" with respect to location as well as in the sense that we are normally unaware of the activities they control.

The Thalamus. The thalamus is a mass of gray matter located at the base of each cerebral hemisphere, as shown in Fig. 14. In the lower vertebrates, it is concerned with mediation of the various senses. With greater and greater development of the cerebral hemispheres, however, these functions were lost, until in man the thalamus is primarily a switchboard for relaying impulses to appropriate regions in the cerebral cortex. Auditory impulses from the ears are shunted to areas 41 and 42 of the cortex, for example, while visual impulses are relayed to area 17. This is not a one-way service, for impulses from the cortex are also sent down to the thalamus, modifying its activity.

Hypothalamus. Below the thalamus is a smaller structure called the hypothalamus (see Fig. 14). Intimately associated with it is the *pituitary gland*, which rises from a stalk jutting out from the bottom of the hypothalamus. We shall say more about this important gland in the next chapter. Anatomists have counted as many as 20 different clusters of cell bodies, or *nuclei*, in the hypothalamic area, but most of their functions are as yet unknown.

As a result of considerable research and clinical observation, it is now generally agreed that the hypothalamus is an important governing center for the autonomic nervous system (see discussion of this division on pages 45 to 47). It has a dual autonomic mechanism. The anterior nuclei are concerned with parasympathetic activity and produce such effects as slowing of the heart rate, dilation of blood vessels, drop in blood pressure, bladder constriction, and increased digestive activity. The posterior nuclei, on the other hand, produce sympathetic effects such as rise in blood pressure, acceleration of heart rate, dilation of the pupils, and decrease in digestive activity.

In addition to its dual autonomic role, the hypothalamus also contains structures which control such general activities as (1) water, carbohydrate, and fat metabolism; (2) temperature regulation; (3) sleeping-waking activity; (4) sexual functions; and (5) emotional behavior.

Cerebellum. The cerebellum lies below the occipital lobes of the cerebral hemispheres, toward the back of the brain. In structure it is very similar to the cerebrum, for it is also divided into two hemispheres with numerous sulci and gyri, and its outer surface also consists of gray matter surrounding an inner mass of white matter.

The functions of the cerebellum are not entirely known. During phylogenesis it is closely related to such coordinated motor activities as swimming, walking, and flying. It is now generally believed that the major

function of the human cerebellum is to time the actions of various muscles involved in a specific act so that the component movements may be smoothly and effectively executed.

Medulla Oblongata. Just before we reach the spinal-cord level in our downward progression, we come to the medulla oblongata, often called simply the "medulla." It is really an upper extension of the spinal cord. Through it course the ascending and descending nerve tracts en route to higher or lower levels.

Apart from relaying impulses, the medulla has other functions. Electrostimulation and other techniques have revealed that it contains nuclei which control heart rate, blood pressure, and respiration, thus making it indispensable to life itself.

Spinal Cord. We have now scanned several of the essential parts of the brain. Let us next glance briefly at the spinal cord, a cylindrical structure about 18 in. long in the human adult. It extends from the lower end of the medulla to the lower lumbar, or back, region. Like the brain, the spinal cord is surrounded by three meninges. Protecting both cord and meninges is the long, bony, jointed vertebral column.
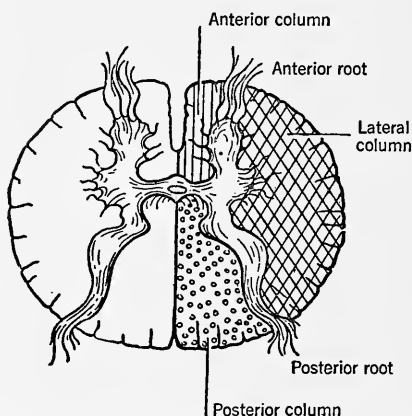

Fig. 16. A cross section of the spinal cord showing the H-shaped central mass of gray matter and the three columns—anterior, lateral, and posterior—of one side. (*From Best, C. H., and Taylor, N. B. The human body and its functions. New York: Holt, 1946. P. 258. By permission of the publishers.*)

A section at any level of the spinal cord will reveal that its center, or core, consists of an H-shaped mass of gray matter comprised, in turn, of nerve-cell bodies. The broader of the two arms of the H are called *anterior horns*, while the more slender back limbs are known as *posterior horns*. The part of the cord outside this central mass is made up of long, myelinized fibers arranged in bundles. Because of the white color of the myelin, the white matter of the spinal cord is on the outside, in direct contrast to the brain arrangement. In each half of the cord, fiber bundles are divided by the horns into three groups to form the anterior, lateral, and posterior columns shown in Fig. 16.

In general, the anterior columns of the cord contain pathways which conduct impulses downward from the higher centers and are therefore motor in nature—for example, the pyramidal, or corticospinal, tract mentioned earlier. The posterior columns, on the other hand, relay impulses

upward and hence are sensory. Impulses from the muscles, tendons, and joints, for instance, course upward through the posterior columns to reach the thalamus and the cerebral cortex. The lateral columns contain both sensory and motor pathways.

Peripheral Nervous System

Outside the central nervous system but attached to the spinal cord and brain are nerves and collections of cell bodies, called *ganglia*, which collectively constitute the peripheral nervous system. For convenience in discussion, the peripheral nervous system may be divided into two parts: the *cerebrospinal nerves* and the *peripheral parts of the autonomic system*. It must be remembered, however, that such a division is arbitrary and is made only to facilitate discussion.

Cerebrospinal Nerves. This subsystem sends impulses initiated by either external or internal stimuli into the central nervous system and conveys impulses back to the peripheral organs of response. On anatomical grounds, it may be subdivided into (1) *cranial* and (2) *spinal nerves*.

The 12 pairs of cranial nerves are attached directly to the lower levels of the brain. Nerves of smell, taste, sight, and hearing as well as those which serve the skin of the face belong in this group.

The 31 pairs of spinal nerves are segmentally attached to the spinal cord and are classified according to the body region which they innervate. Each nerve is connected to the spinal cord by a posterior root consisting of sensory fibers and an anterior root of motor fibers. Thus, in a simple reflex reaction, an impulse may be conducted through the sensory fibers to the cord and shunted across to a motor fiber through which it is conducted back to a peripheral muscle without reaching any level of the brain.

Peripheral Autonomic Nervous System. The autonomic nervous system controls the heart, smooth muscles of the viscera, skin, and glands. It is often called the *involuntary system*, because it concerns functions of which we are normally unaware. On both anatomic and physiological grounds, it may be subdivided into two parts: the *sympathetic* and the *parasympathetic*, illustrated in Fig. 17. Both of these are important to an understanding of emotional behavior.

Sympathetic System. The sympathetic division consists of long "knotted" cords of nervous tissue, called *ganglion chains*. These descend one on each side of the spinal column, sending out fibers intermittently to such organs as the heart, iris, glands, blood vessels, stomach, and intestines. Some of the innumerable structures innervated are shown in Fig. 17.

In general, the sympathetic system may be said to function in the mobilization of body resources for special emergencies. Examples of sympathetic reactions are the constriction of blood vessels of the viscera in

order to shunt the blood supply into muscles and brain; dilation of the bronchioles to increase oxygen intake; widening of pupils to admit more light; increase in blood-sugar level to stimulate the liver and adrenal glands. Such reactions step up the activity level of the body. As might be
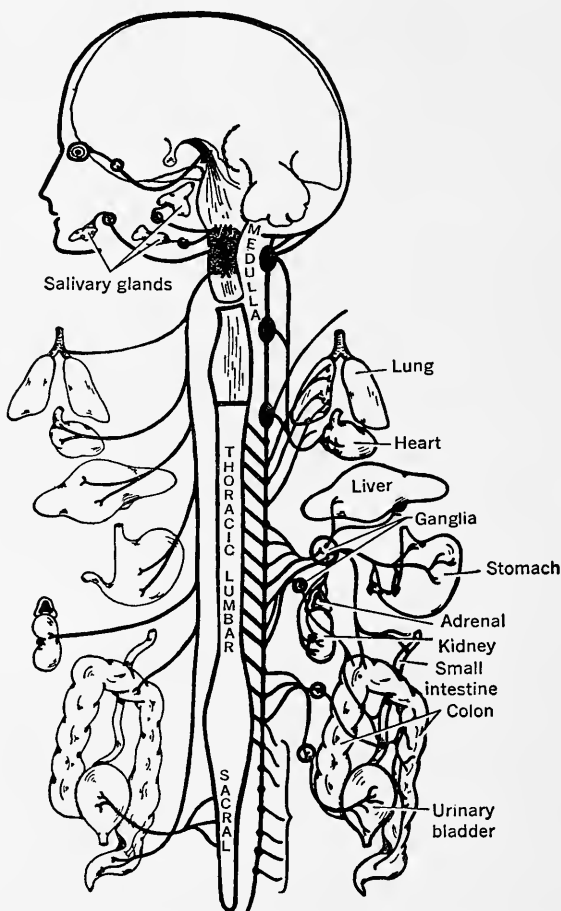

Fig. 17. The autonomic nervous system of man. The sympathetic system is shown on the right and the parasympathetic on the left. (*From Strausbaugh, P. D., and Weimer, B. R. General biology. New York: Wiley, 1947. P. 231. By permission of the publishers.*)

expected, the sympathetic system is especially active in emotion-provoking situations.

Parasympathetic System. The nerves which form the parasympathetic division branch out from the cranial region of the brain and from the lower segments of the spinal cord. For this reason it is frequently referred to as the *craniosacral division* (see Fig. 17). Perhaps the two best-known nerves with parasympathetic function are the *vagus* and the *pelvic.* The vagus nerve descends from the brain to innervate such structures as the heart,

bronchioles, stomach, intestines, and pancreas. The pelvic nerve, on the other hand, arises from the sacral region of the spinal cord to innervate the large bowel, rectum, bladder, and sex organs.

Whereas the sympathetic system is concerned chiefly with the mobilization of body resources, the parasympathetic system may be said to conserve them. Thus, the cranial division stimulates the flow of gastric and salivary juices to aid digestion. Through slowing down the heart rate and dilating the blood vessels, thereby reducing blood pressure, it reduces the energy consumption of the body. Through innervation of the colon, rectum, and bladder, the sacral division disposes of the toxic waste products of the organism.

Antagonistic Action. As we have just seen, the sympathetic and parasympathetic systems innervate organs located in diverse parts of the body. Figure 17 indicates that such structures as the iris of the eye, heart, stomach, bladder, intestines, and sex organs are innervated by both autonomic divisions. In general, the action of these sets of fibers is antagonistic. Although a number of exceptions may occur, the sympathetic fibers usually speed up heart rate, dilate the pupils and bronchioles, and inhibit digestion, while the parasympathetic fibers decrease heart rate, constrict pupils and bronchioles, and facilitate digestion. This double innervation of many of the body organs, coupled with the antagonistic action of the two autonomic systems, is extremely important, because it provides a stable autonomic equilibrium for the body.

Higher Autonomic Centers. The discussion of the autonomic divisions has so far been concerned chiefly with the peripheral parts which relay impulses to and from the central nervous system. There are a number of higher autonomic centers, however. These are located within the central system, in the medulla, hypothalamus, and cerebral cortex. They serve to integrate some of the more specific reactions occurring at the spinal level. As has already been observed, the hypothalamus governs both divisions, with the anterior nuclei performing parasympathetic functions and the posterior nuclei performing sympathetic roles. Furthermore, through its neural connections with the pituitary gland, the hypothalamus is able to bring glandular reactions into line with the autonomic picture. Controlling the hypothalamic centers through both direct and indirect pathways are the impulses emanating from the cerebral cortex. It is common knowledge, for instance, that the mere thought of an unpleasant experience can produce such autonomic effects as increased heart rate, perspiration, and pallor.

ONTOGENETIC CHANGES IN THE NERVOUS SYSTEM

So far we have briefly examined the evolution of the nervous system and its structure and function in the human adult. With this material as back-

ground, let us now see how this intricate communication network develops and what happens to it once the peak of development has passed. As we trace the ontogenetic changes, we shall also see various accompanying changes in behavioral reactions.

Periods of Prenatal Development

Before concentrating on neural development per se, let us look quickly at the general pattern of early growth and development of the human organism from the time of fertilization to birth. This entire period covers 10 lunar months of 280 days, or 9 calendar months. It has been subdivided by embryologists into three periods: the period of the egg, or ovum, the embryonic period, and the fetal period. Each of these is characterized by its own developmental pattern. They will be discussed in the order in which they occur.

Period of the Ovum. This is the shortest phase of development, including only the first 2 weeks after fertilization. As was observed in Chapter 2, human development begins with the penetration of the ovum by a sperm —a process known as fertilization. During the first 2 weeks the fertilized ovum, or zygote, as it is now called, increases little in size, but some remarkable changes occur internally. Soon after fertilization the ovum begins to subdivide by the mitotic process discussed earlier. The cells multiply in geometric progression until they eventually account for the billions present at the time of birth. As mitosis proceeds, cells begin to differentiate both histologically and physiologically to form bone, muscle, and the various organs of the body.

During these early days the ovum remains free and unattached. Toward the end of the period, however, its outer surface becomes embedded in the uterus lining of the mother. From this time until birth the organism is a parasite, receiving its nourishment from the mother's blood stream and growing rapidly in size.

Embryonic Period. The interval from the end of the second week, when the ovum becomes embedded in the uterus, until the end of the second month is known as the embryonic period, and for 6 weeks the growing organism is called an embryo. Soon after implantation, the ovum, which by now consists of a globular mass of many cells, begins to differentiate into three layers: an external ectoderm, an intermediate mesoderm, and an inner endoderm. From these layers the various body organs later develop. The *ectoderm*, or "outer skin," gives rise to such varied organs as the central and peripheral nervous systems, the skin and its derivatives, skin glands, hair, sense organs, salivary glands, and anterior lobe of the pituitary. From the *mesoderm*, or "middle skin" layer, arise the skeleton, muscles, connective tissues, heart, blood vessels, and urogenital system. Finally, the *endoderm*, or "inner skin," is the origin of the lungs; various

parts of the alimentary canal; and endocrine glands such as the thymus, thyroid, parathyroid, and pancreas.

Growth and developmental rates are tremendous during this period. By the end of the second month, the embryo has increased in mass by 2 million per cent, and differentiation of body structures is 95 per cent complete. The rudiments of the later adult structures are evident in a primitive nervous system, in the beginnings of eyes and ears, skeleton and
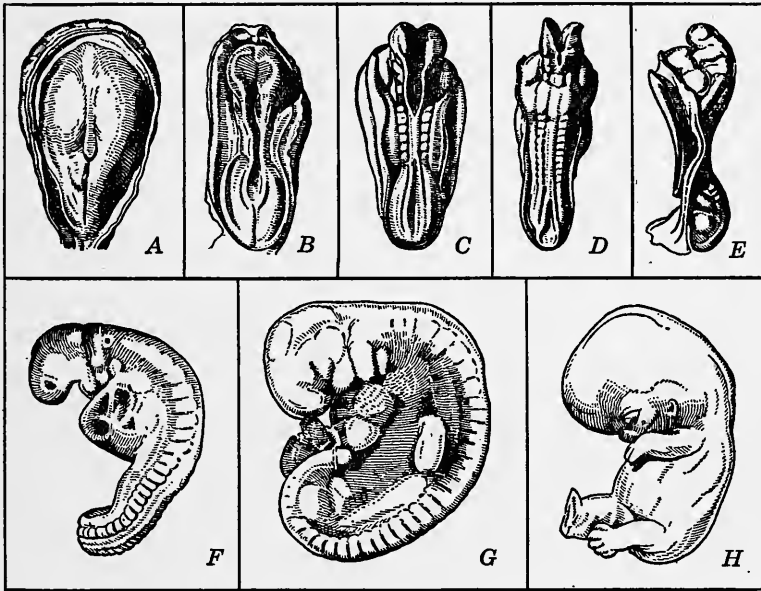

FIG. 18. Development of the human embryo from the sixteenth day to the eighth week. A, embryo aged about 16 days, enlarged × 23.5; B, about 18 days, × 22; C, about 19 days, × 18; D, about 20 days, × 18; E, about 22 days, × 12; F, about fourth week, × 9.5; G, about fifth week, × 6.5; H, about eighth week, × 2. (*After Streeter. From Brooks, F. D. Child psychology. Boston: Houghton Mifflin, 1937. P. 32. By permission of the publishers.*)

muscles, and in the four limbs. The microscopic size of these body parts becomes apparent, however, when we consider that at the end of the embryonic period the whole organism is only 2 in. long and weighs less than 1 oz.

The gross structural changes of the embryonic period are clearly shown in Fig. 18. It may be readily seen that by the end of this phase the embryo has assumed the typical human form but differs considerably from a newborn baby. Its head is enormous in proportion to the rest of the body; its arms and legs are miniatures, with fingers and toes not yet completely separated from each other. Nevertheless, it could no longer be mistaken for a lower-animal form.

Fetal Period. The remaining 8 lunar months of prenatal life are known as the fetal period, and the organism is called a fetus until the time of birth. Fetal development is characterized chiefly by growth in size and further development of the structures which appeared in rudimentary form in the young embryo. Few new structures appear. During the early fetal period growth is accomplished chiefly through a continuous process of mitosis, but in the later fetal months it results primarily from increase in size of individual cells rather than from formation of new cells. Structures such as the nervous system, glands, skeleton, muscles, and sense organs reach a much higher degree of development by the time of normal birth. More will be said about these later.

Prenatal Development of the Nervous System

Because of its close relationship to behavior, prenatal development of the nervous system is of considerable importance. It is one of the first of the body systems to become clearly differentiated. Let us follow its development briefly.

Early Differentiation and Growth. As has been observed, the nervous system derives from the ectodermal embryonic layer. Shortly after implantation in the uterus, this outer layer develops a groove extending along almost the entire length of the embryo, as shown in Fig. 19A. As time goes on, this neural groove folds inward and is sealed off to form a hollow tube (Fig. 19B). The lower part of the tube eventually becomes the spinal cord, while the upper part forms the brain.
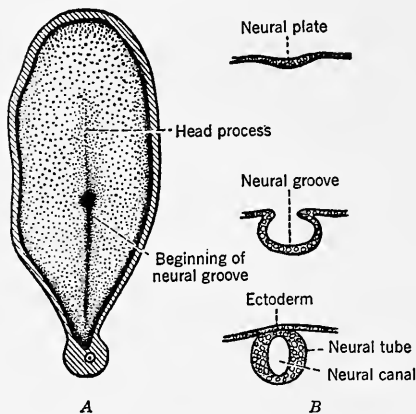

FIG. 19. Stages in the early development of the nervous system. A, a 19-day human embryo; B, development of the neural tube. (From Munn, N. L. Psychology. Boston: Houghton Mifflin, 1946. P. 59. By permission of the publishers.)

The nervous system follows the general growth pattern already outlined. Early differentiation is extremely rapid. By the third fetal month, the brain has acquired all its principal structural features. Although the main structures are present, however, they do not function effectively until around the time of birth. As with other systems, the changes which occur during the later prenatal period are primarily related to increase in size and in complexity. For example, the surface of the brain, which was smooth at first, begins to *evaginate,* or fold in upon itself, to form the sulci and gyri with which we are familiar (see Fig. 20).

As nerve fibers grow out of (or into) the brain and cord, various nerve pathways develop. The earliest tracts in the cord itself may be seen as early as the second month. Pathways joining the spinal cord with higher centers emerge later. For example, the great pyramidal tract which governs voluntary movements of muscles does not begin its downward course until the fifth prenatal month.

General Stages of Development. Generally speaking, early neural development is characterized by the establishment of the basic elements of the nervous system; by a gross organization of the spinal cord; and by the emergence, growth, and general arrangement of the ganglia and neurons
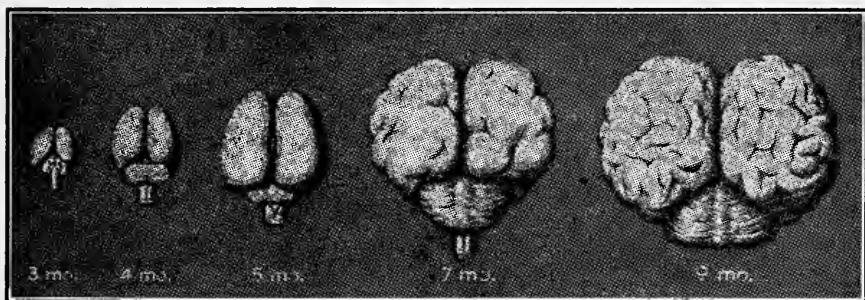

FIG. 20. Growth of the brain during the fetal period. Note the increase in size and the presence of convolutions by the seventh fetal month. (*After Retzius and Broman; Gilbert. From Munn, N. L. Psychology, Boston: Houghton Mifflin, 1951. P. 79. By permission of the publishers.*)

of both the central and peripheral systems. The late fetal period represents further differentiation of the higher brain centers, increase in size of the hemispheres, appearance of convolutions, development of neural interconnections with higher centers, and, finally, the beginning of myelinization of nerve fibers—in short, by such factors as relate to the finer coordination of behavior.

Myelinization of Nerve Fibers. Once the neural pathways have been formed, many of them begin to acquire a whitish, fatty covering called a myelin sheath. The process of myelinization begins around mid-fetal life and continues well past the age of puberty. Approximately half of the fibers become myelinized after birth. It is interesting that, in the lower animals that can stand and run directly after birth (*e.g.*, chicks), myelinization is further advanced at birth than in human beings, who are relatively helpless at that age.

Not all the various neural pathways receive their myelin sheaths at the same time. Sensory pathways of the spinal cord begin myelinization around the fifth fetal month, whereas fibers of the pyramidal tract show no traces of myelin until the second postnatal month and are almost com-

pletely covered by the second year—about the time the child "learns" to walk. Myelinization of the brain regions comes even later. It begins around the time of birth and continues into the teens.

Myelinization and Function. Not many years ago, the question of whether myelinization was or was not an essential prerequisite to neurally controlled behavior was considered of primary importance and was vigorously debated. As with many other problems, the findings of various studies have shifted this emphasis.

The question goes back to Flechsig, who, toward the close of the nineteenth century, stated that the development of a myelin sheath was a necessary antecedent of neural activity. This view received stanch support from such men as Tilney and Casamajor (1924), who claimed to have found a close relationship between time of myelinization and beginning of reflex responses in the cat fetus. The weight of experimental evidence is against any such close correlation, however (Watson, 1903; Angulo, 1929, 1932; Langworthy, 1928, 1929, 1933). Langworthy, for example, who studied fetuses of both cats and opossums, observed that while the relationship between myelinization and onset of behavior patterns seemed to be fairly close, reflex behavior nonetheless preceded myelinization of the fibers involved, in many instances. A little later he noted similar results in human fetuses and, in addition, observed a marked acceleration in myelinization following birth. Since this acceleration occurred in premature infants as well as in babies born at full term, it appeared to indicate that the myelinization rate was influenced by environmental conditions.

On the basis of this and other experimental evidence, it is now believed that the relationship between myelinization and behavior is a reciprocal one. On the one hand, myelinization plays a role in facilitating the onset of behavior; on the other hand, behavior serves to accelerate myelinization rate.

Prenatal Development of Neural and Neuromuscular Activity

The earliest movements of the developing organism are independent of neural control. The first observed movement is the beating of the heart. This occurs as early as 3 weeks after fertilization, when the outgrowing axons of nerves have not yet reached the heart. During early development, localized movements of small groups of muscles can be elicited by direct stimulation of the muscle with an electric current. This does not occur in real life, however, for normal functioning of all muscles depends on sensorimotor connections. About the fourth week, peripheral nerve fibers gradually begin to make their way from the spinal cord and brain toward the various organs, and incipient behavior is aroused and con-

trolled by the nervous system. It is therefore referred to as neuromuscular activity.

Principles of Behavioral Development. For many years one of the great arguments among students of behavior has concerned the nature of early responses. Are the earliest fetal responses reflexes which are later integrated into patterns, or is activity of a "mass" nature which later differentiates or "individuates" into specific reflexes and response patterns? Attempts to answer this question have been numerous. Only a few examples will be mentioned here.

Coghill's Study. The classic investigation in this field was done by Coghill (1929), who studied the *amblystoma*, an amphibian. This organism was selected because the young are independent of the mother and accessible to direct observation through a translucent shell. At various developmental stages, Coghill stimulated the embryo with a human hair and noted the nature of the responses.

At the earliest stages, the organism did not respond to touch. Later, the first response was characterized by a bending of the head to one side; the lower part of the body was not yet sensitive. Stimulation of a slightly older embryo produced a bending response which extended down the entire body, resembling the letter "C." In a still older organism, a double bend, or coil, appeared, resembling the letter "S." Such double flexion approximates the early form of swimming movements. Still later, the limbs as well as the trunk participated in the reaction—first the forelimbs and later the hind limbs—but at first the limbs served only as a part of the total body reaction, and only later were the legs able to move independently of the body. In turn, this reaction was followed by independent movements of knees, feet, and toes.

Coghill coined the term *individuation* to sum up these observations. By individuation he meant that development proceeds from gross muscle responses to smaller and finer movements—a progressive differentiation of refined responses from the original diffuse mass reaction. In his own words, "the nervous system concerns itself first with the maintenance of the integrity of the individual, and only later makes provision for local reflexes."

These experiments gave rise to two other general principles, or "laws," of behavior, less controversial and quite generally accepted. The first is the well-known *cephalo-caudal* principle, which states that development proceeds in a head-to-tail temporal and spatial sequence. The other is the less well-known *proximo-distal* principle, according to which development proceeds from the central axis of the body in an outward direction.

Other Studies. Coghill's findings precipitated a large amount of research on animals at various levels of the phylogenetic scale. Kuo (1932), work-

ing with chick embryos, supported Coghill's conclusions. Orr and Windle (1934), also working with chicks, supported the cephalo-caudal principle but reported equivocal results as far as individuation was concerned, for, in addition to locomotor patterns emerging in line with this view, they also found an independent emergence of some reflexes prior to mass response. Other investigators contributed to both sides of the controversy. Angulo (1932) reported individuation in the albino rat, but Windle and Baxter (1936), who worked with the same subspecies, failed to support this finding. Windle and Griffin (1931) reported that individuation seemed to be the general rule in fetal cats but that reflexes often emerged independent of mass movements. Hooker (1936), in a series of observations on human fetuses, corroborated Coghillian principles.

On the basis of these and many other studies (see Carmichael, 1946, for review), neither the view that reflexes differentiate out from a generalized pattern of activity nor the view that larger behavior patterns result from an integration of separate reflexes has been definitely established. A probable cause of the discrepant findings is suggested in a very important study of fetal guinea pigs by Carmichael and Smith (1939). They found that by varying the intensity of tactual stimulation, either a specific or a mass response could be elicited. A just-above-threshold stimulus, for example, evoked a local response, while a strong stimulus elicited mass movement. These findings mean that little reliance can be placed on any of the earlier, less carefully controlled studies of any species. Before the controversy can be settled, we need further experiments in which stimulus intensity is rigidly controlled.

Although the cephalo-caudal and proximo-distal principles have been generally accepted, it must be remembered that frequently responses appear which seemingly contradict these sequences. These principles will be referred to again in subsequent sections.

Studies of Human Fetuses. Data on behavior of human fetuses are difficult to obtain. Such sources of information as the reports of mothers concerning early fetal movements or the recording of such movements through the body wall of the mother are of limited scientific value and often entirely untrustworthy. The best data in this area derive from the study of fetuses which, for reason of the mother's health, have had to be delivered by Caesarean operation. After removal, such fetuses are immediately placed in a physiological solution at blood temperature in order to prolong life as much as possible under these abnormal conditions. Since the fetuses are deprived of their oxygen supply, however, they are gradually asphyxiated and can be studied for only a limited period.

The most extensive studies of such fetuses have been made by Minkowski (1922), Bolaffio and Artom (1924), and Hooker (1936). The earlier investigators relied on stenographic records of fetal responses, but Hooker

used moving pictures, thus providing a permanent record of responses. The stimuli used to elicit movements are usually human hairs, but occasionally investigators have employed needles, cactus thorns, or electric currents. Thompson (1952) summarized the literature on the nature of responses of such surgically removed fetuses, separating them into age groups. This summary is given below. A more comprehensive survey of the literature is provided by Carmichael (1946).

First Month. The beginning of heartbeat occurs in the third week when the embryo is only about four mm. in length. It is independent of neural control.

Second Month. By the sixth week the elements necessary for a spinal reflex are formed, but no spinal reflexes appear before the eighth week. Muscular activity can be elicited by direct electrical stimulation. A spontaneous, wormlike movement of the arms, legs and trunk has been observed during the last week of this period.

Third Month. Spontaneous movements of a slow, uncoordinated type appear. The fetus responds to tactual stimulation—first in the oral-nasal region. The palmar (grasp) reflex appears before the plantar (foot) response. The sum total of responses during the latter part of this period involves movement at every joint, and almost every possible type of movement at each joint. Withdrawal of the head from the point of stimulation has been observed. Sectioning of the spinal cord indicates that the reflexes present are dependent on reflex arcs involving this part of the central nervous system. Respiratory movements have been noted near the close of this period.

Fourth Month. By this stage of development all of the discrete reflexes that can be observed in the normal infant are present—excepting functional respiration and vocal response. Many of these reflexes are sluggish and uncertain of appearance, however. The human fetus has advanced from the more general, stereotyped response to a group of discrete reflexes which are fundamental to human behavior. Destruction of various portions of the spinal cord causes the disappearance of functionally related reflexes while total destruction of the cord leaves no reflex behavior other than responses to direct muscle stimulation. The fetus' activity and reflexes are not appreciably altered when the cerebral cortex is removed, indicating an absence of cerebral control at this time. Almost all of the body's surface is sensitive to tactual stimulation during the latter part of this period.

Fifth Month. The grasp and Babinski reflexes can be readily elicited and the "trot reflex," supposed to underlie later locomotor activity, appears. Respiratory movements can be evoked by stimulation of the medulla. By this stage of development generalized body activity has so increased in intensity that the average mother has no difficulty in reporting strong fetal movements. . . . Hiccups have been observed in the fetus during this period occurring about fifteen to thirty times a minute.

Sixth Month. Respiratory movements are more apparent upon stimulating the medulla. Because of continuing differentiation of body movements, it is possible to identify several of the tendon reflexes with greater certainty, for example, knee jerk and Achilles tendon reflex. Sucking reflexes can be evoked by tactual stimulation of mouth and tongue.

Seventh Month. Reflexes are more pronounced and intense, for example, grasping. Crying appears. Stimulation of the lower brain centers affects body movements, but the cerebral cortex still appears not to be involved in the control of behavior. Fetuses born during the latter part of this period have a fair chance for survival when given special care.

Eighth Month until Birth. Available evidence indicates that the cerebral cortex has little, if any, control over the fetus' behavior patterns. Almost all of the tendon reflexes are clearly differentiated and can be easily observed upon proper stimulation. Almost all of the responses that can be evoked from the normal, newborn infant can also be elicited during this period. The fetus born during this period has a good chance for survival with proper care [pages 43–44. Cited by permission of the publishers].

The above summary of the development of function in the human organism illustrates very well the principles of behavioral development discussed earlier. Especially clear is the gradual individuation of various behavior patterns from earlier generalized movements. It is important to note, however, that most of the above protocol is based on evidence reported by Hooker (1936), who is a stanch supporter of the Coghillian school.

Growth and Development of Neural Structure and Function after Birth

We now have a general picture of neural and neuromuscular development up to the time of birth. It will be immediately recalled that birth marks a change only in the organism's environment—not in its growth and developmental patterns. This environmental change cannot be minimized, however, for it separates the erstwhile parasite from his ready source of food, oxygen, and other necessaries, forcing him to fend for himself for the first time. Usually he meets this need with a lusty yell of protest, the "birth cry." For the first time, his earlier respiratory movements are indispensable, his own digestive apparatus essential, his own efforts necessary to eliminate wastes, and his own vocalizations needed to call attention to his immediate needs. He is bombarded by hundreds of unaccustomed stimuli from the new external environment. He must immediately adapt to all of these if he is to survive. His nervous system is accordingly called upon for adjustments and coordinations not required during prenatal life. Let us therefore examine what little evidence we have on postnatal development.

Gross Structural Development. As was noted earlier, prenatal growth of the nervous system is achieved through an increase in the number of cells. By the time of birth, this mitotic division has ceased. Postnatal growth is accordingly due to the increase in size of each immature cell. Apart from size, postnatal development is further characterized by changes in the nature of neural connections.

Accurate information on the growth of the brain is difficult to find. Such data as we have at present have been obtained chiefly by examination of the brains of individuals already dead or by estimates based on external measurements of the craniums of living children and adults.

At birth, the brain weighs about 10 or 12 oz. as compared with the adult weight of $2\frac{1}{2}$ to 3 lb. Growth of the brain is very rapid from birth to the fourth year. At this time the brain has attained roughly 80 per cent of its adult size, and by 6 years, 90 per cent. From the age of 6, brain size and weight increase more slowly, reaching adult status around the sixteenth year. Different parts of the brain, however, have different growth rates. For example, the cerebellum attains 80 per cent of adult weight at the end of the second year but does not reach adult status until adolescence.

Microscopic Aspects of Brain Development. Accompanying the increase in size are certain important internal changes—for example, growth in size of cells, in fiber extensions, and in myelinization in the various areas. As we mentioned earlier, myelinization of the pyramidal tract does not begin until 2 months after birth and is not completed until much later. Some interesting behavioral changes accompany this process. Prior to the second year, for example, stimulation of the sole of the foot produces a fanning of the toes, the so-called *Babinski reflex.* After the age of 2, a similar stimulus evokes a downward flexion of the toes known as the *plantar response.* The Babinski reflex frequently reappears in adults when the pyramidal tract has been injured.

At birth, the cerebral cortex is largely unmyelinized. The extent of myelinization, together with other features such as the size and shape of cells and the number and extensiveness of dendrites, has been explored by several investigators in an attempt to determine the course of maturation of various cortical areas. One of these investigators, De Crinis (1932), who studied 68 human brains ranging from 5 days to 13 years of age, reported that the visual, auditory, and somesthetic areas were the first to mature. These were followed shortly by the motor cortex. The so-called "association" areas, however, were not fully mature by the age of 13. De Crinis's conception of the sequence of maturation is illustrated in Fig. 21.

More recently, Conel (1939, 1941) reported the initial findings of a very comprehensive study of brain development. These reports concerned development during the first postnatal month. According to his data, the most advanced development is found in area 4, the motor cortex, slightly less in the sensory areas, and least in the front half of the frontal lobes. This is essentially in agreement with De Crinis except for the position of the motor cortex. Presumably Conel's research provides the more accurate picture, however, since he investigated a number of structural elements such as size and shape of cells, presence of neurofibrils, and quan-

tity of myelin, while De Crinis studied only the nature of dendritic processes in the different areas of the cortex.

One of the most interesting findings of Conel was that the area of the motor cortex which mediates movement of the head-shoulder region is furthest advanced at birth, while the area governing limb movements is poorly developed but advances considerably during the first month. This suggests that development of cortical control of neuromuscular activity proceeds essentially in a cephalo-caudal direction. It is also interesting to note that, as far as locomotor development is concerned, the infant gains

Early maturing areas
Later maturing areas
Latest maturing areas
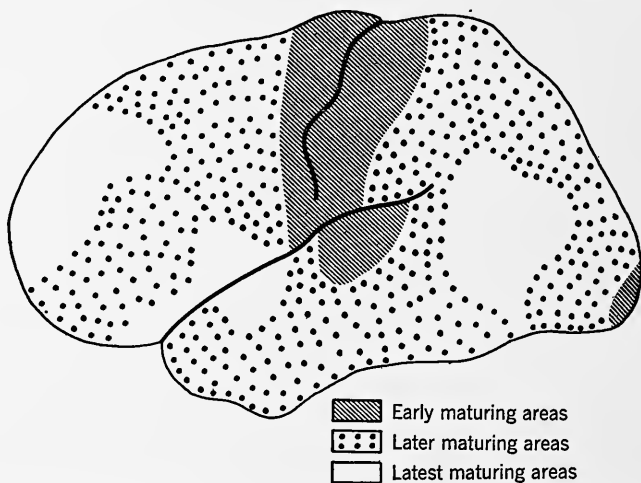
Fig. 21. Diagram showing the order in which different areas of the human cortex mature. (*Based on diagram of De Crinis, 1932.*)

control over the head before the limbs. The locomotor sequence will be discussed further in Chapter 6.

Electrical Activity of the Brain. In addition to the anatomic methods illustrated above, postnatal development can also be studied by *electroencephalography*. This technique consists of placing electrodes on various parts of the skull, thus recording the electrical potentials generated by the brain. Such potentials are commonly referred to as *brain waves*, or EEG's.

Of the various kinds of brain waves the best known are the alpha, beta, and delta waves. *Alpha waves* have a frequency of 9 to 12 cycles per sec. They can be recorded in any part of the brain but are strongest in the occipital region. They are generally considered to be the "normal" brain waves of the human adult, present in a wakeful but relaxed state. *Beta waves* are high-frequency rhythms of 18 to 20 cycles per sec. Like the alpha waves, they may be recorded over the entire cortical surface but predominate in the frontal areas. Lastly, the *delta waves* are very slow rhythms of 2 or 3 cycles per sec. or even less. They occur randomly during

sleep. In the adult, appearance of delta waves at any other time is considered evidence of pathological brain disturbance—for example, tumor.

Age Changes. A number of investigators have studied age changes in brain waves. EEG records taken at birth indicate an absence of *rhythmical* potentials throughout the cortex. Whatever activity can be picked up is of a very irregular nature, as evidenced by shape and size of recorded "waves" as well as by their low amplitude (see Gibbs and Gibbs, 1941).
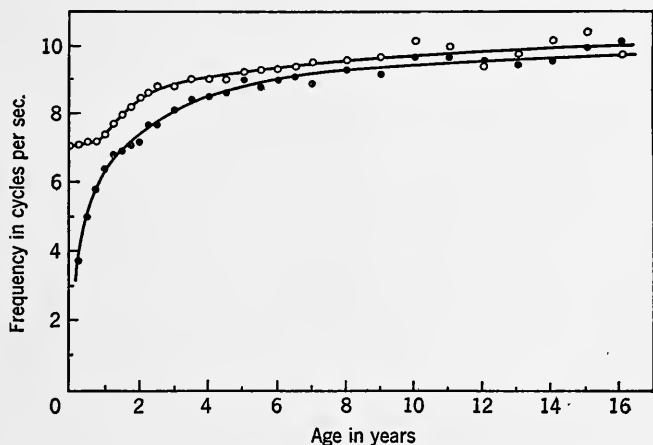
FIG. 22. Increase with age in the frequency of the alpha rhythm. The upper curve indicates the frequency from the central region over Brodmann areas 3, 1, 2, and 4; the lower curve refers to the occipital alpha rhythm. (*After Smith, J. R. The frequency growth of the human alpha rhythm during normal infancy and childhood. J. Psychol.*, 1941, **11**, 188. *By permission of the Journal Press.*)

Smith (1941), who took special care to record EEG activity only when the neonate's bodily activity was at a minimum (for instance, in the initial stages of drowsiness), was able to record alpha waves of about 7 cycles in the central region of the cortex, the motor area. No such rhythms appeared in any other area. This finding is in line with Conel's (1939) results, which were discussed earlier. It will be recalled that Conel reported that cells of area 4 were most advanced in development at birth. The occipital cortex, which is the chief source of alpha waves in adults, first showed rhythmic waves of 3 to 4 cycles around the fourth month. Figure 22 graphically illustrates the development of alpha waves in the central and occipital regions, showing clearly the gradual rise to adult frequency by the twelfth year.

Figure 23 shows an interesting record of a longitudinal study of development of occipital alpha rhythm in a boy from birth to the age of 10 years. This demonstrates clearly the absence of rhythmical activity during the first 3 months, the onset of 4-cycle alpha rhythms at 4 months, and the gradual increase in frequency until adult level is reached at 10 years.

Lindsley (1951) believes that this increase in frequency with age is related to myelinization and other developmental processes.

In summarizing the literature, Gibbs and Gibbs (1941) add that, although the occipital and central alpha rhythms attain adult frequency
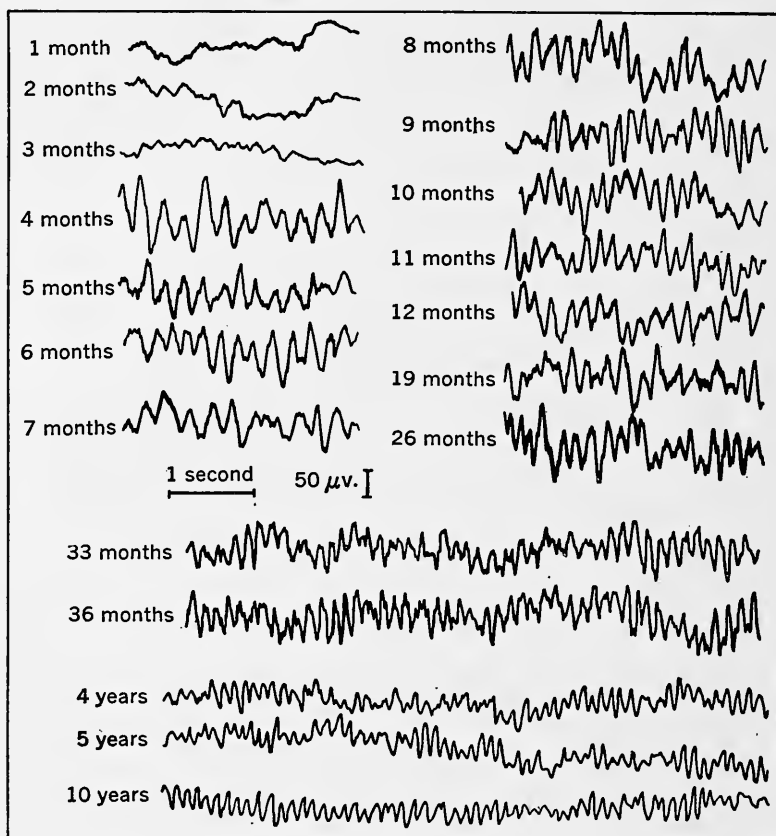

FIG. 23. Development of the occipital alpha rhythm in a boy from birth to 10 years. Note the onset of the rhythm at 4 months and the increase thereafter with age. (*From Lindsley. In L. A. Jeffress (Ed.), Cerebral mechanisms in behavior. New York: Wiley, 1951. P. 278. By permission of the publishers.*)

around the twelfth year, the alpha waves in the frontal cortex are still poorly developed at this time. Even during the age range of 14 to 17 years, waves with frequencies as low as 5 to 7 cycles are common in the frontal regions, and it is not until the age of 19 or 20 that adult patterns are found in all cortical areas. Others place the age of maturity in this respect at anywhere between 19 and 30 years (Bernhard and Skoglund, 1939). Thus it seems that the order in which the various cortical areas attain adult electrical characteristics corresponds closely with the differ-

ential sequence of structural maturation as revealed by anatomic studies to date.

Brain Waves and Behavior. Just what these ontogenetic changes in brain waves signify as far as behavior is concerned is difficult to say, with our present knowledge. The rudimentary nature of brain waves during the first few months of postnatal life is in keeping with the widely held view that the cerebral cortex of the neonate functions little, if at all. Evidence of this appears in cases of children born without cerebral hemispheres. Such children have the same repertory of reflex responses as normal neonates (see Dennis, 1943).

Certain changes in reflex behavior accompany cortical development as gauged by EEG's, however. The grasp reflex serves as an excellent illustration. It is pronounced in infants but becomes progressively weaker until it disappears entirely around the sixth month. This "fading out" of the grasp reflex has been correlated with the gradual maturation of the motor cortex, for if area 4 is destroyed in adults the grasp reflex will be reinstated (Richter and Hines, 1934).

Apart from such correlations, we can say little about the behavioral significance of age changes in brain waves at present. Undoubtedly they are related in some way yet unknown to the great sensory, motor, intellectual, and other changes which characterize the child and adolescent years. Some believe, for example, that the ontogenetic changes in emotional states may depend to some extent on development of the frontal lobes, as gauged by age changes in brain waves (Bousfield and Orbison, 1952). Again, the attainment of "peak" intellectual development during late adolescence (see Chap. 10) may be a reflection of the fact that it is not until this age period has been reached that adult EEG patterns are found in all cortical areas.

Age Changes in the Nervous System in Later Life

Let us next see what happens to the nervous system once the peak of development has been reached. The literature on the senescent human brain presents difficulties both in obtaining sufficiently large samples and in interpreting the findings. The difficulty in interpretation arises because, with advancing age, changes occur in various physiological processes such as circulation of the blood or metabolic activities which strongly influence neural well-being and efficiency. Deterioration of the cerebral blood vessels, for example, would impair the blood supply to the brain and hence its nutritive supply—so essential to the proper functioning of the brain. Infections of various kinds are also fairly common among the aged. Accordingly, if or when structural changes are found in brain tissues, the question immediately arises whether such changes represent normal aging

or whether they are secondary, resulting from infection, disturbed blood supply, or malnutrition.

As a result of such difficulties in interpreting data, many controversies have arisen, in turn resulting in two schools of thought. One of these schools regards aging of the nervous system as an inevitable and essentially physiological process (*e.g.*, Warthin, 1929). The second school, perhaps best represented by Tilney (1928), believes that there is no such thing as a strictly "old" brain. It is true, say adherents of this school, that the brains of the aged may show structural and functional changes, but these changes are secondary, resulting from pathological assaults (infections, metabolic changes, etc.) on the neural tissues throughout the individual's lifetime. Before we sum up the evidence for or against either school, let us examine the data available.

Gross Structural Changes. The earliest study of the aged human brain dates from the time of William Harvey (1635). At the request of Charles I of England, Harvey performed an autopsy on a farm hand, Thomas Parr, who died at the ripe old age of 152 years, 9 months. Parr, it seems, continued in excellent health throughout his lifetime and was capable of threshing corn (no mean task in those days) when he was 130 years old. In describing Parr's brain, Harvey tersely stated that it was "healthy, firm and hard to touch." Scattered throughout the medical records of the next 300 years are other such casual observations of aged brains. It is only within the last 25 years, however, that any serious anatomic studies have been undertaken.

A gross postmortem examination of the aged brain reveals that with advancing age the meninges become quite thick and often adhere to and are difficult to detach from the underlying cortex. The cerebral cortex becomes characterized by convolutions, shrunken in size, and separated by deep, wide fissures (Fig. 24). This shrinkage is most conspicuous in the front two-thirds of the hemispheres. The *pons*, cerebellum, and midbrain also shrink, but not so much as the cerebral hemispheres (Critchley, 1942). In view of shrinkage, a decrease in weight might be anticipated. In the only extensive study available, it was found that brain weight remains fairly constant at 1,400 grams during the age span of 20 to 60 years but decreases thereafter to average only 1,000 grams by the age of 85 (Roessle and Roulet, 1932). Apart from these decrements in size and weight, most of the brain changes are of microscopic nature.

Cerebral Hemispheres. Shrinkage in the size of the hemispheres is partly due to decrease in size of the individual nerve cells. Although this occurs generally throughout the brain, it is thought to be most prevalent in the frontal and occipital lobes (see Carlson, 1949). In addition to decrease in the size of cells, other changes have been reported. One investigator who studied 24 elderly brains (age 66 to 100 years) and others who

studied 25 aged cases observed that cells became more irregular and showed internal changes such as absence of Nissl substance and loss in staining properties in the cell nucleus (Rothschild, 1937; Andrew and Cardwell, 1940). Still others report infiltration of pigments and fatty
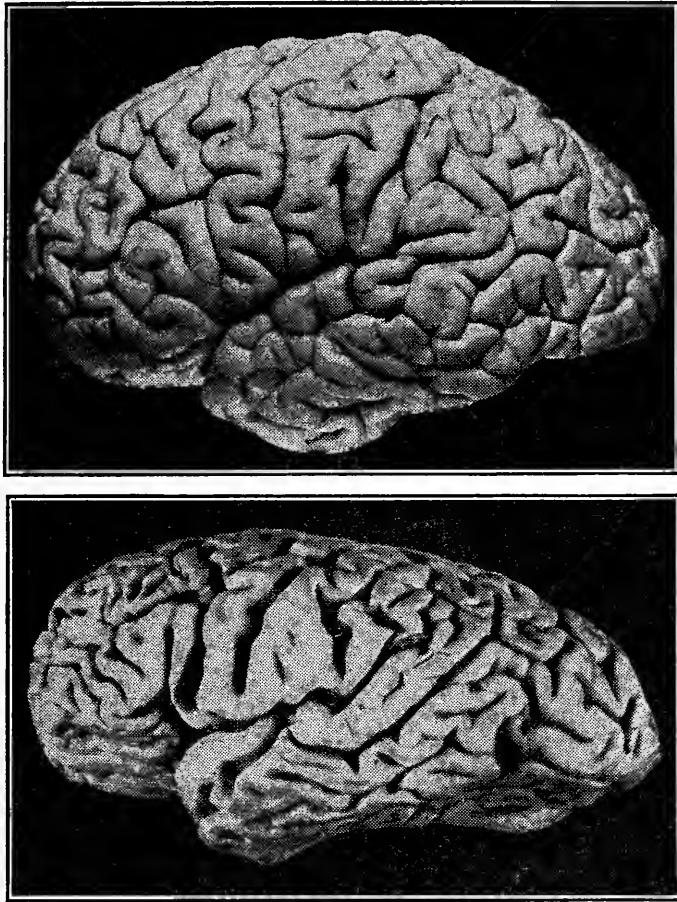

FIG. 24. Photographs showing appearance of brain in adulthood (above) and in old age (below). Note the deep, wide fissures and the narrow convolutions, especially noticeable in the frontal lobe, in the aged brain (74 years). This brain weighed only 900 grams, whereas the average adult brain weighs around 1,400 grams. (*Adult brain obtained from Gardner, E. G. Fundamentals of neurology. Philadelphia: Saunders, 1952. Aged brain obtained through courtesy of Dr. Winfred Overholser, superintendent, Saint Elizabeths Hospital, Washington, D.C.*)

substances into the nerve cells (Critchley, 1942; Truex and Zwemer, 1942). Both Critchley (1942) and Rothschild (1937) assert that, in addition to the degenerative changes mentioned above, some cells completely disappear.

The disappearance of cells is corroborated by Andrew (1939) and by Andrew and Cardwell (1940), who made an extensive study of both human beings and mice. They describe how some of the nerve cells in the aged brain are swallowed up in an interesting way. The glial cells forming the supporting structure of the nervous system increase in size and number, gradually surrounding the nerve cells and slowly destroying them through a process called *neuronophagia*. These investigators report that neuronophagia occasionally occurred in young organisms as well, but, interestingly, whenever observed in young subjects, the nerve cell was "attacked" by only one or two glial cells. In older persons, perhaps four or five or more glial cells moved in on the nerve cell, making the swallowing-up process more inevitable and more rapid.

Other changes have been noted. Whether or not neuronophagia occurs, the glial cells increase in size and number. Doubtless this increase in supporting structures accounts for the maintenance of normal brain weight despite loss of nerve cells. The increase in glial cells is especially conspicuous in the occipital region. Various degenerative changes in cerebral blood vessels have also been observed (Critchley, 1942).

Individual Differences. The discussion thus far has implied that these degenerative changes occur in all aged brains. Actually, some of the old brains examined have shown few degenerative changes, while others from comparatively young individuals have revealed considerable structural deterioration. It was these individual differences which led O'Leary (1952) to suggest that perhaps genetically determined factors play an important role in determining the nervous system's susceptibility to aging. So far, we lack data to support or refute his suggestion. The differential degree of atrophy may relate to the finding that some old people have remarkably well-preserved intellectual powers while others show considerable loss (see Chapter 10).

Physical Activity and Aging of the Nervous System. A well-known neuroanatomist recently made some detailed histological studies of aged brains (Vogt, 1951). He reported that during the aging process nerve cells exert various counterreactions in an attempt to delay deterioration as much as possible. In some cases, the cell nucleus became larger, and more Nissl substance was found in the cell body. These counterreactions and others were especially noticeable in persons who led active lives. In studying brains of persons over the age of 90 who had been physically active all their lives, he found that the "aging changes of the nerve cells were . . . considerably delayed."

Since these findings were presented only in abstract form, they are difficult to evaluate. However, if the implied thesis—that exercise throughout the years serves to delay the aging of the nervous system—can be substantiated, its practical value will be tremendous.

Subcortical Structures. Structural changes similar to those occurring in the cerebral cortex (shrinkage and loss of cells, pigmentation, fatty infiltration, etc.) have been observed in various subcortical centers such as the thalamus and basal ganglia. These degenerative changes seem to be least obvious in the "vegetative centers of the hypothalamus" (Critchley, 1942). This is corroborated by the finding that at least some of the hypothalamic nuclei continue to be normal in persons 100 years old (Vogt, 1951).
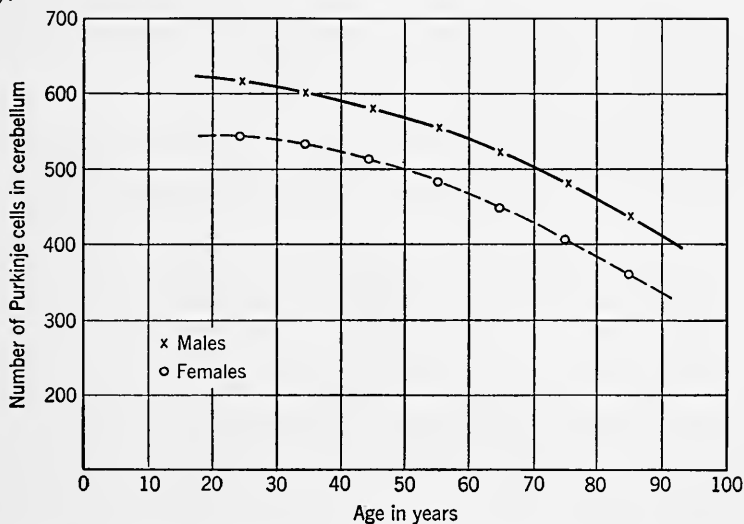
FIG. 25. Loss of Purkinje cells (cerebellum) with age. (*After Ellis, R. S. Norms for some structural changes in the human cerebellum from birth to old age. J. comp. Neurol., 1920, 32, 24.*)

One of the most resistant of the hypothalamic group is the *supraoptic nucleus*, which gives rise to the important neural tract innervating the pituitary gland. Among structures which age early, on the other hand, are the basal ganglia. These ganglia, it will be recalled, serve to link the cerebellum with area 6 of the cortex, forming a neural system concerned with the coordination of body movements. It appears, therefore, that the brain structures controlling vegetative processes essential to the life of the organism—for example, circulation, respiration, digestion, and sleep—are most resistant to aging, while other centers not so vital to life may atrophy earlier.

Cerebellum. As previously mentioned, the cerebellum is concerned with coordination of body movements. Ellis (1920) studied the cerebellums of 63 human subjects ranging in age from 12 to 92 years. He counted the number of Purkinje cells present in the cerebellum at various ages. The results of his study are shown in Fig. 25. There is evidently a loss of cells beginning during the fourth decade. By the age of 80, the cumulative

loss represents roughly one-third of the original cell count. Ellis believes that the sex differences shown in the figure are not statistically significant. In addition to the loss of cells illustrated in the diagram, such other changes as shrinkage in size of cells, loss of Nissl substance, and increased pigmentation were noted. All of the changes were observed not only in the cerebellar cortex but also in the structures deep within the cerebellum. These findings were corroborated by another study reporting degenerative changes, especially loss of Nissl substance in the Purkinje cells, in subjects over the age of 50 years (Andrew, 1938).

Present evidence thus indicates that the cerebellum and the basal ganglia—a system concerned with control of movements—show progressive deterioration with advancing age. It is likely that aging of this system is partly responsible for such things as the slowing down of locomotion, the shortening of stride, the unsteady gait, the loss of adeptness of fine movements, and the hand tremor found in varying degrees in older people. It must not be forgotten, however, that such behavioral changes may also reflect structural changes in joints, skeleton, and muscles.

Pyramidal Tract. Since the pyramidal tract has been mentioned several times, it will be remembered that it is concerned with voluntary movement. An extremely interesting study of the aging of this tract has been reported (Lassek, 1942). Lassek made a section through the medulla of seven brains and counted the number of fibers comprising the tract at different ages from birth to 80 years. He noted a sixfold increase in cross-sectional area between birth and 22 years, most of it occurring during the first year of life. In the single 80-year-old subject, the pyramidal tract had decreased approximately 38 per cent in area and had lost roughly one-third of its fibers. It is unfortunate that more cases were not used, especially in the age range from 22 to 80 years. Nevertheless, it is interesting that the decrease in number of fibers is of the same order as the decrease in number of cerebellar cells reported by Ellis. Lassek believes that the degenerative changes in the pyramidal tract may account for the loss in speed and flexibility of voluntary movements common to old age.

The Spinal Cord and Peripheral Nerves. As we move downward to the level of the spinal cord, we find deterioration similar in kind and quantity to that of the brain. The meninges surrounding the cord thicken, the cord itself may shrink, the contrast between gray and white matter decreases, and the supporting glial cells greatly increase in size and number.

In keeping with the changes in the central nervous system, the peripheral nerves also show degeneration with advancing age. In one investigation, the spinal nerves of 62 bodies ranging from birth to 90 years were removed and counted (Cobrin and Gardner, 1937, 1940). The results of the counts are shown in Fig. 26. A rapid increase in the number of myelinized fibers appeared from birth until the late teens, when the mature count was achieved. This remained constant until the age of 30, when a

slow but steady decline set in. By the eighth decade, the cumulative decrements amounted to roughly 27 per cent—approximately the same degree of loss as has already been noted for the cerebellum and pyramidal tract.

In another study, the same investigators counted the number of spinal-nerve ganglia in 31 bodies aged 34 to 85 years. They observed a sharp drop
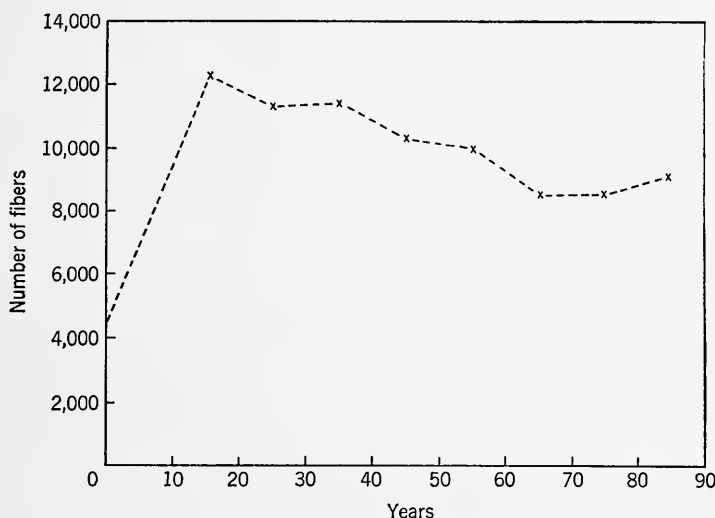

FIG. 26. Age changes in number of myelinized fibers in human spinal nerves (9th thoracic). (*From Gardner, E. D. Decrease in human neurons with age. Anat. Rec.,* 1940, **77**, 533. *By permission of the publishers.*)

in number of ganglia beginning around the age of 45 and approximating a 30 per cent loss by 65 years, after which the number remained constant until the age of 85. It is interesting, indeed, to note that in these few scattered studies the decrements observed in diverse parts of the nervous system are all of the same order: spinal-root fibers 27 per cent; ganglion cells, 30 per cent; pyramidal tract and Purkinje cells of the cerebellum, each roughly one-third.

One other study extends these data. Cottrell (1940), who studied the apparently normal peripheral nerves of 30 individuals ranging in age from 3 to 80 years, reports a reduction in the number of fibers beginning around the fourth or fifth decade and becoming more and more pronounced with advancing years. He also noted degeneration of myelin sheaths and an accumulation of connective tissue and glial cells around the nerves. He maintains that degeneration of these peripheral fibers may account for decreased skin sensitivity in older people.

Peripheral Autonomic Nervous System. Our knowledge of age changes in the autonomic nervous system is restricted to studies of the sympathetic chain of ganglia. Data on 50 cases (aged 5 months to 78 years) re-

veal that the ganglion chain in young children has only long dendritic processes (Kuntz, 1938). During late childhood and adolescence, short dendrites branch off from the ganglion cells, so that by adulthood dendrites of varying lengths are common. Furthermore, it has been noted that new short dendrites continue to arise during adulthood and even in later life. It has been suggested that the ganglion cells of the autonomic system may continue to differentiate throughout life.

However, several investigators have observed what appear to be degenerative changes in the sympathetic ganglia (Kuntz, 1938; Gatenby and Moussa, 1951). Dendrites show irregular thickenings and tend to become winding; some loss of Nissl substance occurs, and excessive pigment is deposited in the cells after the age of 40. Since these structural changes were absent in many subjects, it was suggested that they may be due not to age but to pathological causes.

In summary, it may be said that the autonomic centers in both the central nervous system (*e.g.*, hypothalamus) and the peripheral system seem to resist degenerative changes. This is not surprising, since the autonomic system is so essential in controlling the vital functions of the body.

Physiological Changes. In view of the extensive structural changes in both the central and peripheral nervous systems, impairment in function might be anticipated. This has been experimentally confirmed. Let us look at a few indications of physiological changes.

Electrical Activity of the Brain. Perhaps the best indexes of changing neural activity are the alterations in brain waves in older people. A study has recently been reported of 150 males between 65 and 95 years of age who were "of reasonably sound physical and mental health" (Obrist, 1951, 1952). EEG recordings were taken from the major brain areas and compared with similar records of young adults. The most striking age difference is the greater incidence of slow waves in older subjects. The alpha waves become significantly less frequent with age, while delta-wave activity becomes more frequent. When the elderly subjects were divided into two age groups of 65 to 79 and 80 to 94, a greater incidence of slow waves was noted in the older group. This slowing of brain-wave activity seemed to be general throughout the whole cortex. Such EEG changes, indicating as they do a depression of neural activity, are undoubtedly related to the decline in such psychological processes as learning, memory, and intelligence (see Chapters 9 and 10).

Conduction Rates of Nerves. Degenerative changes in the peripheral nerves result in certain functional changes. Wagman and Lesse (1952) measured the conduction velocity of impulses in the ulnar nerve of the palm in 93 subjects, aged $3\frac{1}{2}$ to 82 years. They found that adult velocity of neural conduction was 59 meters per sec. This velocity is attained by the age of 4 and remains fairly constant through early and adult life, decreasing after the age of 60. The decline in conduction rate is without

doubt one of the factors underlying the increase in reaction time common to old age (see Chapter 6).

Reflex Responses. As might be expected, reflexes are altered in many "healthy" senescents. One of the earliest to change is the pupillary reflex, which becomes sluggish in its response to light. Other reflexes which grow sluggish and in many cases are entirely absent are the knee and ankle jerks. Of all reflexes normal to adulthood, the plantar response persists longest. Individual differences are great, however. Some subjects over 60 years of age may exhibit sluggish responses or lack reflexes while others give no evidence of change (Critchley, 1942; Howell, 1949). In interpreting these observations, we must remember that failure to elicit a response may be a result of muscular or other changes and hence cannot be attributed to neural deterioration alone.

The widespread structural changes in the nervous system of the aged are reflected in behavioral areas other than reflexes. Much of the deterioration in sensory and motor functions, learning, and intelligence is undoubtedly related to aging of the nervous system. Studies correlating structural with behavioral change are exceedingly rare, however.

General Comments. Earlier in this section, mention was made of the two schools of thought regarding aging of the nervous system; the first school regarded it as an inevitable and essentially physiological process like growth, while the second considered it a product of the pathological assaults throughout the individual's lifetime. The studies discussed above support the first thesis. For the most part, these investigations were carefully executed, and their results suggest a consistent pattern of deterioration or, in certain instances, consistent absence of change at all levels of the nervous system. It is most interesting that such a consistent pattern should emerge from relatively few studies based on small samples.

Further, and perhaps stronger, support for the first school of thought is offered by recent findings that loss of neurons—a main feature of the aging process—occurs even during the period of growth and differentiation as early as the embryonic stage (Hamburger and Levi-Montalcini, 1949). In concluding a review of age changes in this field and commenting on this last finding, O'Leary (1952) states that "this suggests that cellular loss in the nervous system can be a general component of overall biological design, though ordinarily it is held in abeyance from fetal life to the onset of senium."

While most of the studies challenge the "disease" theory, they cannot at present refute it. The old nature-nurture controversy therefore permeates even this area of research. Perhaps the best view to take at the present time, as ably stated by Critchley (1942), is that "aging of the nervous system is not entirely a simple physiological process nor yet an exclusively pathological one. It is to be inferred that both features are operative though their relationship cannot as yet be determined."

GLANDULAR DEVELOPMENT

Of all normal body structures, perhaps second to the nervous system in its implications for behavior is the system of glands that largely maintains the chemical balance of the organism. Some knowledge about these glands is necessary to an understanding of such processes as skeletal, muscular, and emotional development.

Duct and Ductless Glands. A gland is a group of cells which has become specialized to secrete or to excrete chemical substances. The secretory type abstracts certain materials from the blood, changes them to form new products, or isolates a part of them and transmits the modified product to other body tissues where they are used. Excretory cells perform an essentially similar function, except that the substances taken from the blood are waste materials destined to be eliminated from the body. When the glandular structure is such that the products are transmitted through a definite opening, it is known as an *exocrine*, or *duct*, gland. When the products are transmitted through the cell wall into the blood stream or lymph, the structure is referred to as an *endocrine*, or *ductless*, gland.

Evolution. The evolution of duct glands is obscure. In such organs as the pancreas and liver, duct glands appear to be emergent organs in vertebrates. On the other hand, what look like salivary glands are found in mollusks and arthropods where they seem to perform a lubricating rather than a digestive function. Only in mammals do the true enzyme-secreting salivary glands appear. Endocrine glands are thought to be peculiar to vertebrates; homologous organs are entirely lacking in lower forms. Further reference to evolutionary origins will be made in the discussions of specific glands.

DUCT GLANDS

The exocrine, or duct, glands discharge their contents onto the surface of the body or into various cavities. Some of the duct glands perform an excretory function; others are secretory in nature.

Excretory Duct Glands. The excretory glands are fewer in number than the secretory. In this group are the *sweat* glands, which form an avenue

for removal of wastes and help to regulate temperature; the *sebaceous,* or oil, glands which condition the skin; and the *lachrymal,* or tear, glands which lubricate the eyes. Among them are also the kidneys, perhaps the most important excretory organs of the body, and the liver, another secreter of waste products.

Sweat glands—especially those of the armpits—become particularly active around puberty and give off large amounts of perspiration, much to the annoyance of growing youngsters. Similarly, the sebaceous glands increase in size and activity and are responsible for many of the skin disturbances, such as blackheads and acne, so frequent among adolescents. Activity of these glands remains quite high well into middle life (Way, 1931). In later years, degenerative changes result in decreased output (Hirsch, 1926), perhaps accounting for the dry skin of old people.

Secretory Duct Glands. Most important of this group are the glands concerned with digestive functions. These are found primarily in the walls of the alimentary canal. Pouring their secretions of saliva into the mouth cavity are three pairs of *salivary* glands; other duct glands are found in the stomach, intestines, pancreas, and liver. In addition to these digestive glands, there are the *mammary* glands, which secrete the milk essential to the nourishment of the infant, and the *sex* glands, which play a role in reproductive functions.

The output of enzymes concerned with digestion of starches, proteins, and fats is very low during the early months of life but increases so rapidly that by the end of the first year the enzymes which act on starches and proteins have virtually reached adult level. Those concerned with fat metabolism lag behind, and it is not until the twelfth year that they approximate adult status (Ivy and Grossman, 1952). This, of course, has implications for infant and child diet.

The most extensive study of later-age changes in enzyme output is reported by Meyer and Necheles (1940), who investigated age changes in salivary, gastric, and pancreatic secretions. They compared a group of older people whose mean age was 81 with a younger control group with a mean age of 25. Saliva output decreased—accounting for the tongue dryness of older people—and the output of salivary enzymes acting on starches (*ptyalin*) diminished, indicating that the first step of starch digestion is depressed in older subjects. Beyond the age of 60, some decrease was noted in the *pepsin* of the gastric glands, which breaks down proteins. Pancreatic *trypsin,* which also acts on proteins, showed slight decline; pancreatic *amylase,* involved in starch digestion, and *lipase,* concerned with the breakdown of fats, showed no significant age differences. Thus it seems that although digestion of starches, proteins, and fats may be impaired in its early stages in the mouth and stomach, digestion through pancreatic secretions at the intestinal level remains relatively intact and

is carried to completion here. On the basis of these results, Meyer and Necheles conclude that the diet restrictions imposed on the aged, through fear of curtailed enzyme activity with consequent failure of digestion of either carbohydrates, fats, or proteins, are unjustified. According to these investigators, many digestive disturbances and many of the special diets for the aged are "based on fear and habit rather than on basic physiological changes."

Enzymes and Behavior

Enzymes are involved not only in the chemical reactions of digestion but also in various chemical events occurring in tissues in general. They break down food materials into simpler elements which provide energy for liberation of heat, mechanical work of the muscles, and the biochemical processes underlying neural activity. In addition, the simple elements, or building blocks, are again synthesized to produce more complex substances through the action of enzymes.

Although the importance of enzymes in the metabolic activities of the body has been recognized for many years, investigators have only recently begun to recognize their significance in behavior and to note that disturbances may lead to certain abnormalities in behavior (see Morgan and Stellar, 1950). Before discussing this relationship, let us examine the nature of the enzyme more closely.

Nature of Enzymes. Enzymes are complex substances which act as catalysts, speeding up the chemical reactions of the body but are not consumed themselves, and hence may be used over and over again. They are composed of a number of elements, perhaps the most important being a protein substance called an *apo-enzyme*. This apo-enzyme is generally found in an inactive state in the cell producing it. Before it can assume any catalytic properties it must be attached to a class of nonprotein substances called *co-enzymes*, or *prosthetic groups*, collectively referred to as *activators*. The apo-enzyme plus the activator form the free enzyme with catalytic properties. Many of the vitamins exert their effects on the body through their roles as activators.

In actual practice, a number of enzymes catalyze chemical reactions in a chainlike manner. For example, in the breakdown of glucose into simpler compounds, about 20 steps are involved, each step occurring in a constant order and promoted by a specific enzyme. Some enzymes work very quickly; others less quickly or slowly. This means that, since each acts in its turn in the series, the over-all metabolic rate depends on the slowest member of the enzyme chain. The slowest member, which sets the pace for metabolism, has been called the *pacemaker* (Hoagland, 1944). Any condition which causes the pacemaker to shift will therefore also change the

over-all rate of the chemical reaction. This in turn is often followed by behavioral changes.

Role of Enzymes in Animal Behavior. Several lines of evidence suggest that changes in enzyme function are reflected in behavior. Biochemists tell us that in invertebrates such as the firefly, for example, the production of luminescence depends on a series of steps, each catalyzed by an enzyme system as shown below:

$$A \longrightarrow B \longrightarrow C \longrightarrow D \ldots \ldots \ldots \longrightarrow \text{Luminescence}$$
$$\text{Enzyme 1} \quad \text{Enzyme 2} \quad \text{Enzyme 3} \quad \text{Enzyme 4, etc.} \ldots$$
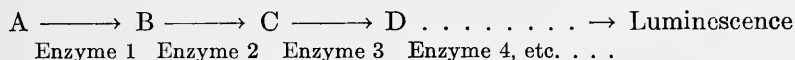
If we experimentally block or slow down one of the catalytic agents by arsenic or X ray, for example, luminescence will not occur. Let us consider another illustration. Morgan and Groody (1946) observed that, when certain proteins were omitted from the diet of dogs, the animals became very agitated, ran around frantically, and showed various fear reactions. As soon as the proteins were restored to the diet, the dogs resumed their normal behavior. Since we know that enzymes are of a protein nature, it is quite likely that the unusual behavioral patterns were caused by a disturbance of enzyme activity.

Role of Enzymes in Human Behavior. It has already been mentioned that certain of the vitamins serve as activators. One of these is *niacin*, of the B-complex group. A severe lack of niacin results in pellagra, characterized by such psychological symptoms as loss of memory, nervousness, and occasionally pronounced fears, delusions, or hallucinations. These symptoms can be dramatically reduced or eliminated by administration of niacin, which functions as a co-enzyme in the oxidation of glucose (Spies *et al.*, 1938). It is therefore apparent that malfunction of a certain enzyme system underlies these abnormal behavioral changes. Another illustration of the importance of enzymes in behavior is phenylpyruvic oligophrenia, a type of mental deficiency brought about as a result of the absence of a certain enzyme system (see Chapter 2). On the basis of these and other data, Hoagland (1936, 1947) developed the hypothesis that the roots of many human psychoses lie in disturbances of certain key enzyme systems essential to normal brain metabolism. One of the psychoses which he studied extensively and which bears out his hypothesis is *paresis*. In these experiments he studied the enzyme systems controlling brain waves (alpha rhythm) in normal individuals, partially cured paretics, and highly psychotic paretics. He found that brain-wave activity in all three groups was controlled by a single enzyme pacemaker. The interesting thing, however, was that each group had a different pacemaker. Accordingly, Hoagland argued that many personality changes, especially those which occur

during the *early* stages of paresis, result from changes in enzyme functioning as reflected in change of pacemaker.

Hoagland further believes that many of the temporarily beneficial effects of various shock therapies on certain psychoses may be due to temporary acceleration of certain enzyme systems concerned in brain metabolism. Hoagland's work to date and the hypothesis derived from his work are exciting and challenging. Considerably more research is needed, however, before we can accept the view that psychoses result from failure of enzyme systems.

DUCTLESS GLANDS

General Considerations

Endocrine glands are located in various parts of the body, as shown in Fig. 27. They possess no special outlets but release their secretions of hormones into the blood stream or lymph whence they are transmitted throughout the body.
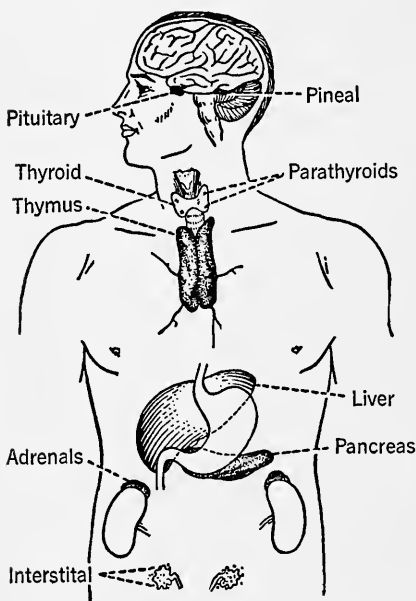
Fig. 27. Sketch showing the general location of the main endocrine glands. (*From Dashiell, J. F. Fundamentals of general psychology. Boston: Houghton Mifflin, 1937. P. 214. By permission of the publishers.*)

Hormones and Enzymes. It is important to note the similarities and relationships between hormones and enzymes. Unlike the vitamins, both are produced by the organism; both are needed in only minute quantities, and both are concerned with metabolic functions. Our knowledge of the relationships between hormones, enzymes, and metabolism is as yet limited. However, we do know that certain hormones can inhibit enzyme activity and, through this, metabolism. Certain extracts of the anterior pituitary, for example, can inhibit the action of an enzyme which breaks down glucose. Thus, some of the effects of hormones on behavior may result via the enzyme → metabolism → behavior chain which we saw operating in the previous section.

Margin of Safety in Glands. Before examining the specific glands in relation to age, let us look at a few of the difficulties confronting investigators in this field of research. Most of the data involve measurement of

size or weight of a gland at different ages. In many texts there are graphs depicting the growth of glands in terms of cumulative or incremental weights or volumes at different stages from birth to adolescence. Such a graph is shown in Fig. 28. The assumption is often made that hormone output parallels such growth curves. This may be quite erroneous, for research has indicated that endocrine glands have a large "margin of safety," that is, they have considerably more glandular tissue than the body needs (see Carlson, 1952). Large fractions of tissue may be removed without in any way disrupting the chemical balance of the body. This, of course, means that an increase or decrease in gross size of a gland may make no difference to the output of the gland and that, even if output were reduced, the body might still have an ample hormone supply. This is particularly important in relation to the shrinkage in size or number of glandular cells which may occur in old age. It is therefore apparent that any interpretation must be based on age changes in actual hormone output rather than on changes in weight or volume; at present, there are few data on such changes. More research is badly needed. A further complicating factor is that we lack norms for actual hormone requirements at various ages. It is thus difficult to say whether a gland is underactive or overactive, especially during later life.

Interdependence of Endocrine Glands. Another problem facing investigators arises from the interdependence of the various glands, for they are organized into a system of balances and counterbalances in such a way that malfunction of one may disrupt the entire system. Accordingly, if a certain gland decreases its hormone output, it is difficult to say whether the behavioral effects are caused by diminished output of this particular hormone or by the resultant hormone imbalance of the entire system. This should be remembered constantly throughout subsequent sections. Keeping these factors in mind, let us now turn to the growth, development, and possible later deterioration of specific glands, emphasizing especially the significance of such changes for behavior.

Thyroid Gland

The thyroid gland is peculiar to vertebrates. In the lower vertebrates it is usually unpaired, but in mammalian forms we find a bilobed structure. The thyroid of man straddles the trachea at a point just below the larynx. Its cells secrete the hormone *thyroxine*, which can now be prepared synthetically and which governs the general rate of oxidation in the body and hence metabolic activity, energy output, etc. It is partly responsible for regulating growth from a prenatal stage to puberty and can affect growth even later.

The thyroid begins its development early in prenatal life, growing rapidly during the second, third, and fourth months. Secretory activity be-

gins around the mid-fetal period (Norris, 1937). Figure 28 graphically represents growth curves for a number of the endocrine glands, including the thyroid, the curves being plotted in terms of postnatal increments, placing birth weight at zero. According to this graph, the thyroid attains its maximum weight between the ages of 15 and 20 years. We do not know
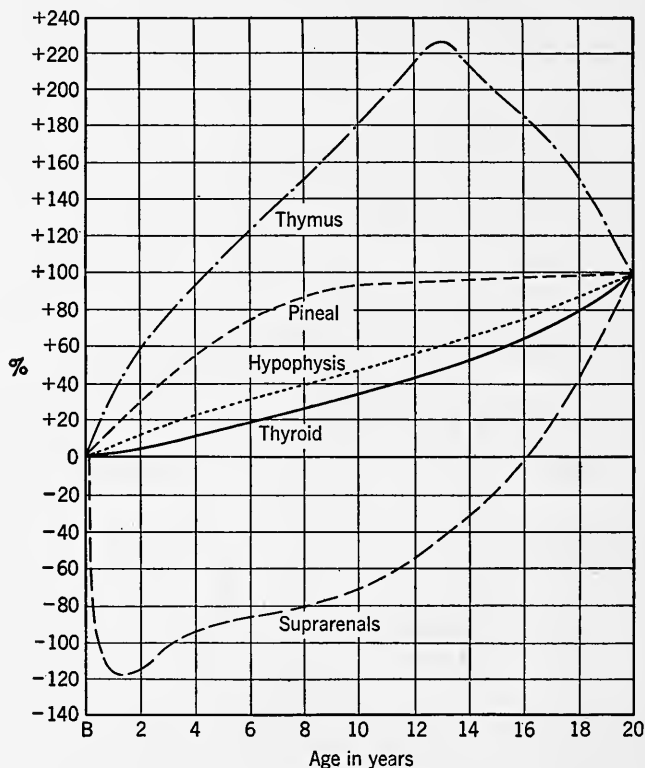

FIG. 28. Growth curves for some of the endocrine glands. The curves are plotted in terms of postnatal increments placing birth weight at zero. (*From Harris, J. A., Jackson, C. M., Paterson, D. G., and Scammon, R. E.   The measurement of man. Minneapolis: University of Minnesota Press, 1930. P. 200. By permission of the publishers.*)

whether thyroxine output also reaches adult level during this period. Cooper (1925), who made a cell count of the thyroid at various ages, inferred that activity increases until puberty, when the thyroid is hyperactive, perhaps accounting for the growth spurt at this time. Activity level then declines abruptly until the age of 25, after which it levels off to a stage which she calls "mild activity" and continues at this level until age 66, when her data end.

Developmental Irregularities. Thyroxine is indispensable to growth. In young children, underactivity of the gland, or *hypothyroidism*, results in

retarded growth and differentiation and in impairment of sexual and intellectual development. One of the commonly known conditions consequent to hypofunction is *cretinism*. The cretin is recognized by retarded or abnormal skeletal growth; the long bones stop growing, and the body becomes poorly proportioned; bones remain "soft," failing to ossify with age; basal metabolic rate is 20 to 40 per cent lower than normal; sexual development is arrested; facial features are often coarse and bloated with broad nose, dry and wrinkled skin, and thickened tongue. Frequently the cretin is a deaf-mute. Mental deficiency depends on the degree of glandular hypofunction but may amount to complete idiocy.

Adult "cretinism" is known as *myxedema*. This designation includes only cases in which the thyroid functioned adequately during growth but, for whatever reason, became underactive after puberty. Aside from skeletal development, the symptoms of myxedema closely parallel those of cretinism: low basal metabolic rate; thick, puffy skin; dry, brittle, and sparse hair; apathetic and sluggish mental activity (although the earlier level of intelligence is usually retained); increase in body fat and consequently in weight; and increased susceptibility to infections.

Overactivity, or *hyperthyroidism*, can also produce structural and behavioral changes, manifested in high metabolic rate with consequent reduction in weight, high blood pressure, insomnia, and extreme nervousness. Such symptoms as protruding eyeballs or precocious sexual development may also occur.

These cases are typical of extreme hypo- or hyperfunction of the thyroid, however. The deviations are usually less marked. A mild hypofunction may manifest itself only in sluggishness difficult to distinguish from the common garden variety of laziness, while mild hyperthyroidism may be expressed in tenseness, restlessness, and irritability. Most children can rely on an adequate thyroid output to bring them to adulthood without mishap. The obese child whose mother fondly overlooks his fatness because "something is wrong with his glands" usually suffers from nothing more serious than an excess of calories.

Changes in Later Life. Even with a possible drop in thyroxine level as suggested by Cooper (1925), thyroxine output suffices for the needs of the adult; it is only rarely that a young adult complains of thyroid malfunction. Investigators have noted, however, that as age advances symptoms resembling those of hypothyroidism appear. The slow, gradual reduction in basal metabolic rate beyond the age of 25 is well established. Weight tends to increase as one approaches middle age; skin becomes dry and wrinkled, while scalp hair becomes increasingly sparse. The investigator therefore asks, "Are these conditions due to progressive reduction in thyroid activity?"

It is generally agreed that in later years the thyroid undergoes degener-

ative changes such as decrease in size and weight and reduction of the size and number of secretory cells (Cooper, 1925; Hertzler, 1939; Mustacchi and Loewenhaupt, 1950; and others). Most investigators interpret this as indicating decreased hormonal output. Unfortunately, no data are available on actual thyroxine output in later years, and the findings of present studies fall short of settling the problem. On the one hand, the thyroid glands of the aged show definite signs of structural and perhaps functional deterioration. On the other hand, it is well established that metabolic rate declines and that skin and hair undergo changes. Accordingly, there is a high correlation between these two events, but correlation does not necessarily imply any cause-effect relationship. We cannot therefore attribute the changes to hypothyroidism, particularly in view of the very large margin of safety of this gland. Furthermore, we often find such things as sparseness of hair in middle-aged or even young persons who show no other signs of hypothyroidism. If underactivity of this gland were at the root of such changes, we might expect an administration of thyroxine to remove the symptoms. Such treatment does not seem to be effective (Carlson, 1952).

It is important to remember that other glands and other body processes are also involved in metabolic activities and hence may be instrumental in producing or aggravating symptoms similar to those of thyroid hypofunction. All investigators stress the need for more research on this problem. We particularly need data on actual hormone output and on specific body requirements at all age levels.

Parathyroid Gland

The parathyroids, usually four in number, are pea-sized bodies embedded in the thyroid tissues but independent of them both in embryonic origin and in function. They occur in all vertebrates except fishes. The secretion of these glands, known as *parathormone*, is concerned with regulation of the calcium metabolism of the body.

Although the thyroids and parathyroids are located in such close proximity to each other, their growth patterns vary greatly. Both become functional during fetal life, but any similarity ends at birth. The male parathyroid grows little during the first 3 postnatal months but thereafter increases rapidly, reaching maximum size in the late 20's. The female glands grow little during the first 10 years and continue to increase in size until the age of 50 years (Gilmour and Martin, 1937). Just what these differential growth rates mean to the two sexes, in relation to either function or behavior, we do not know.

Developmental Irregularities. As has been stated, the parathyroids govern the calcium metabolism of the body. Calcium is a component of all normal animal tissues and fluids, constituting roughly 2 per cent of

adult weight. About 90 per cent of this quantity is found in the skeleton. The bones of an infant are "soft" bones, consisting mainly of cartilage. This hardens, or *ossifies*, with age as calcium is deposited in the cartilage models (see Chapter 5). If this process of bone formation is to proceed normally, optimum functioning of the parathyroids is essential. Should an insufficient amount of parathormone be produced, the calcium content of the blood will be reduced and calcium will not be deposited in the bones. On the other hand, if the glands should become overactive, large amounts of calcium will be withdrawn from the bones, making them soft and easily bent. Thus, malfunction of the parathyroids may effect formation of both skeletal bones and teeth. Such malfunction is rare among children.

Changes in Later Life. It is well known that with advancing years there is a decrease in the power of healing and repairing bones. It has also been observed that calcium salts are deposited in various tissues in old age— for example, in the soft tissues of the arteries, kidneys, and lungs, and especially in tissues which show injury or degeneration. Such deposits lower the functional efficiency of the organs concerned. Because of the importance of the parathyroids in calcium metabolism, the question naturally arises whether such calcium deposits are related to changes in secretory activity of these glands. Unfortunately, we do not know. It has been shown that the male parathyroids gradually decrease in size from the fourth decade, while the female glands diminish from the sixth decade (Gilmour and Martin, 1937). What this means in terms of hormonal output, however, is unknown. We do know that the calcium level of the blood remains within normal limits until the age of 80 and even beyond (Carlson, 1952). The answer to this problem must depend on future research.

Adrenal Gland

The adrenal glands are two pyramidlike structures lying at the top of the kidneys but functionally unrelated to them. A cross-sectional examination of the adrenals shows that they consist of two distinct kinds of tissue—a yellowish outer cortex and a brownish inner medulla. The two tissues differ in embryonic origin. The cortex derives from the same tissue which gives rise to the sex glands (ovaries or testes); the adrenal medulla originates from the same tissue as the sympathetic nervous system. Like the two glands already discussed, the adrenals are strictly vertebrate organs. In the lower vertebrates, the cortex and medulla are separate structures, and it is only in mammals that they come together with the cortex surrounding the medulla.

Early Development. The early development of the adrenals is peculiar. Growth begins early in the fetal period, but the interesting aspect of their development occurs after birth (see Fig. 28). At birth they are quite large.

Almost immediately, however, they begin to decrease rapidly in size until around the second year they have shrunk to roughly 120 per cent below birth weight. At this point growth recommences, slowly at first and then more quickly, until they regain birth weight during early adolescence. It is difficult to say just what this peculiar pattern means functionally or behaviorally.

Bousfield and Orbison (1952) made the interesting suggestion that the structural changes may relate to changes in emotional behavior. It is well known, for example, that children's emotions are brief and transient, becoming more and more prolonged as age increases. Basing their opinion on this well-established fact, Bousfield and Orbison assume that the initial decrease in the size of the gland and its continued small volume throughout early childhood is indicative of a low hormone output. It is also known that, in adults, hormones of the adrenal medulla (*adrenaline*) and extracts from the adrenal cortex (17-*ketosteroids*) are present in large amounts during emotional states. It is therefore assumed by these investigators that the low endocrine output accounts for both the brevity and the lack of depth of childhood emotions. As hormone output increases (as inferred from increases in weight of gland), it accounts for "the increase in vigor of emotional states."

Adrenal Medulla. Since the adrenal medulla and the sympathetic nervous system have a common ancestry, some similarity in function might be expected. In general, this is correct. Most of the effects produced by the hormone of the adrenal medulla, adrenaline, can also be produced by action of the sympathetic system. When adrenaline is released into the blood stream, such effects as the following may be seen: dilation of the air passages of the lungs to admit more oxygen; shunting of the blood to the skeletal muscles; release of sugar from the glycogen stores in the liver, thus postponing fatigue; increase in heart rate and blood pressure; and slowing down of digestive processes. Such effects indicate that the hormone mimics sympathetic influences and serves to reinforce their activity in times of emergency or prolonged stress.

Age Changes. Adrenaline secretion has been reported as early as the twelfth prenatal week, but the concentration during the whole fetal period is low (Keene and Hewer, 1927). Data on output during childhood are entirely lacking. Kobro (1946), who studied hormone output present in the blood of human beings aged 12 to 89, found considerable fluctuation in the amount of adrenaline in an individual from day to day but found no age changes. According to his estimates, the total quantity of adrenaline present in the blood at any age from childhood to senescence approximates 0.22 mg. These measurements, it is significant to note, were made under resting conditions. In view of the importance of adrenaline in preparing the organism for emergencies, it would be interesting to know the adrenal-

ine output under conditions of emotion or stress, especially since it is commonly believed that old people are less capable of adapting to such conditions.

Adrenal Cortex. Unlike the medulla, the adrenal cortex is essential to maintaining life. Removal of two-thirds of the cortex results in death within a few days. The adrenal cortex secretes a number of different hormones. Some of these are concerned with regulating salt and water metabolism, while others are involved in carbohydrate metabolism. It is these hormones whose absence causes death.

Within recent years a number of new substances have been extracted from the cortex. Perhaps the best known of these is *cortisone*, which has received so much publicity in the successful treatment of rheumatoid arthritis and which has also been claimed useful in counteracting surgical and wound shocks and in dealing with infants and senescents. It is reported, for example, to be highly effective in carrying premature infants through critical illnesses and in helping old people to recover from minor aches and inflammations. The production of cortisone as well as other cortical secretions is controlled by one of the hormones of the pituitary gland, ACTH.

Another of the extracts which has received much attention—especially in psychological literature—is a group of substances known as the 17-*ketosteroids*. Certain of these compounds possess a chemical structure very similar to that of sex hormones of the testes and ovaries and are known to have a sexual function. Their effect is well illustrated by cases in which the adrenal cortex becomes hyperactive. In cases of tumor of the cortex, for example, children may exhibit precocious development of sexual organs as well as secondary sex characteristics. Women thus affected may take on a masculine appearance, develop hair growth on face and chest, and assume a mannish disposition.

Age Changes. There are no data on age changes in the hormones controlling salt, water, or carbohydrate metabolism or on age changes in cortisone. On the other hand, literature on age changes in 17-ketosteroid output is extensive (see review of Kirk, 1951). These substances are not produced in measurable quantities until the age of 9 or 10 years, however; after this, output increases rapidly, reaching a peak somewhere around age 25 in both males and females. After the mid-20's, production declines gradually but steadily well on into senescence. It has been suggested that this decline may account for such symptoms as loss of muscular energy and proneness to exhaustion in elderly people (Kountz, 1952).

Work of Selye. Since the early days of Cannon (1929), the adrenal medulla has been given a central role in preparing the organism for emergency reactions, emotions, and stress. More recent research, however, has indicated that the adrenal cortex, too, is important in such functions. It

has been demonstrated that when the organism is exposed to a stressful situation such as heat or cold, to injuries such as burns or shock, or to emotional situations, the adrenal cortex enlarges, increasing its secretory activities (Selye, 1950). This increase in secretory output produces certain physiological changes in the body, enabling it better to cope with emergencies. In some very important animal experiments, Selye showed that, when stress extended over long periods, the adrenal cortex underwent changes indicative of secretory exhaustion and culminating in death. If, on the other hand, stress was less severe or less prolonged, the output level remained high but produced certain abnormal changes in organs such as blood vessels, heart, and kidneys. This resulted in degenerative diseases such as high blood pressure, hardening of the arteries, heart trouble, and kidney disease. The stress tests involved continuous tilting of platforms, activity wheels, cold chambers, etc. Since they indicate that emotion-provoking situations can and do produce physical changes, Selye's results have given considerable impetus to research in the field of psychosomatic medicine.

Stress and Ketosteroid Output. The 17-ketosteroids are especially affected by stressful or emotion-provoking situations. During such activities as performing frustrating tasks, flying, or even getting up in the morning, the 17-ketosteroids present in the urine increase in quantity (Pincus and Hoagland, 1943). As we have seen, the 17-ketosteroid output diminishes in the later years. This, however, is secretion occurring under resting conditions. It would be important to know the relative output of these substances in young and old persons subjected to stress situations. Perhaps the best study to date was done by Pincus (1950). He selected 54 young subjects whose mean age was 32 years and 32 older subjects with a mean age of 77 years. Measurements of ketosteroid output of each subject were recorded prior to the experiment, during the stress situation, and some time after it was over. The stress situation consisted of such tests as pursuit-meter and target-ball frustration tests. No significant differences in the output increases were found for young and old subjects. Accordingly, Pincus suggests that "men surviving to old age without overt ill health or infirmity may preserve relatively intact adrenal cortex mechanisms involved in response to acute stress." It would be interesting to know how these mechanisms would respond to *prolonged* stress. Unfortunately, we have no information as yet.

These results, together with the previously mentioned finding that the adrenaline output remains the same with advancing years and that the sympathetic nervous system shows few if any changes with age (see Chapter 3), indicate that body mechanisms concerned with preparation for "stress and strain" are well preserved in later years—at least for dealing with short-term events.

Pituitary Gland

The pituitary gland is a small, oval-shaped structure located on the undersurface of the brain and joined to it by nerves. For purposes of discussion, it can be divided into two lobes, the anterior and the posterior, each secreting a number of different hormones. The posterior lobe produces two hormones, one concerned with the regulation of water balance and the other with stimulation of the activity of certain smooth muscles of the body. Since neither of these hormones is of particular significance for behavioral development, they will not be discussed here.

Hormones of Anterior Pituitary. The anterior pituitary secretes several hormones, which may be divided into two groups. The first group includes those which affect such processes as skeletal growth; fat, carbohydrate, and protein metabolism; and milk secretion. The second group consists of the so-called *tropic* hormones, substances which affect the activity of other endocrine glands. Among these are ACTH, which controls the activity of the adrenal cortex; *pancreatropic* hormone, which aids the growth and secretion of the pancreas; *thyrotropic* and *parathyrotropic* hormones, which stimulate the thyroid and parathyroids, respectively; and *gonadotropic* hormones, which affect the male and female sex glands. Through these tropic hormones, the pituitary can control the various glands and indirectly the functions which they mediate. If the pituitary is removed, many of these glands undergo degenerative changes, and their hormone output is reduced.

Age Changes in Structure of Pituitary. The pituitary gland assumes a definitive structure by the end of the fourth fetal month. Its growth rate is slow during prepubertal years, accelerating later; the gland attains maximum size and weight around the age of 35. It shows little decline in either weight or volume throughout life (Roessle and Roulet, 1932; Timme *et al.*, 1938). Carlson (1949), who reviewed the literature on the aging of the pituitary, states that "various structural changes have been observed in the pituitaries of old animals, as well as of old people, but in the absence of specific pituitary disease, this endocrine gland appears to be remarkably stable at least up to the age of eighty or one hundred years."

With this over-all view of the pituitary as background, let us next look at some of the hormones and their relevance to growth and development.

Phyone. Phyone is the growth hormone of the anterior pituitary. Indispensable to growth during both childhood and puberty, its continuous secretion enables the child to attain maximum normal body size. Increased production of phyone during childhood accelerates growth rate of the skeleton, especially of the long bones, resulting in *gigantism*. Should excessive secretion occur after growth has been completed, then the skele-

ton can no longer increase in size linearly as the ends of long bones have fused with their shafts (see Chapter 5). Instead, a condition known as *acromegaly* will result. Acromegaly is characterized by thickening of the bones of the face and extremities, which gives them a coarse appearance.

Decreased output of phyone during the growing years retards growth rate and produces *dwarfism*. Interestingly, phyone seems to have its environmental limitations. No tests have been reported for human beings, but Ershoff (1951) conducted some experiments on growing rats. He found that phyone failed to increase growth rates of animals reared at low temperatures (2°C.) but did increase growth rates of animals raised at room temperature. It would be unwise to generalize on the basis of one experiment. We already know, however, that children grow more rapidly during the summer than during the winter in northern climates. We have not considered this finding in terms of phyone secretion or effectiveness, however. Perhaps some day we shall be able to account for the relatively short stature of the Eskimo.

While phyone is the *sine qua non* of growth, we know nothing of the fate of this hormone in later life. Some have suggested that it may contribute to repair of body tissues and to ensuring immunity from disease. On this assumption they have attributed the slowing down of growth and repair with advancing age to a decrease in phyone output. These are only guesses, however. We have no evidence on body needs for phyone beyond puberty, nor have we any data on output in the late years. As Carlson (1952) asserts, this Gordian knot can be untied only by further research.

Gonadotropic Hormones. The transition from childhood to adulthood requires not only phyone but also the gonadotropic hormones of the anterior pituitary. These, as has been mentioned, affect the sex glands. Frank (1935) reported the presence of these hormones in low concentration in the urine of children as young as 4 years. The concentration remains low throughout childhood, however, and increases suddenly just before puberty. Nathanson *et al.* (1941) found a large output in girls shortly after the eleventh birthday and in boys of 13 years. This large output of gonadotropic hormones just before puberty stimulates the immature gonads, promoting rapid sexual maturation. This is accompanied by an increase in the production of male and female sex hormones from the gonads, which in turn stimulate development of the reproductive organs and the secondary sex characteristics. More will be said about these changes in the discussion of sex glands.

Insufficient secretion of gonadotropic hormones during preadolescence retards the normal development of ovaries or testes and, indirectly, causes the reproductive organs to remain in the infantile stage; secondary sex characteristics will also fail to develop. Excessive output, on the other hand, may produce precocious sexual development.

During the reproductive years, gonadotropic-hormone output maintains a high level. It was formerly argued that the menopause resulted from a decrease in gonadotropic hormones in females. Recent evidence appears to refute this view. Studies of individuals ranging in age from maturity to the 90's show no decrease in output of these hormones—indeed, the output of females seems to increase after the menopause for a period of several years and perhaps into old age (Saxton and Loeb, 1937; Heller and Shipley, 1951). Thus the early failure of the ovaries and the later failure of the testes cannot be ascribed to declining production of the pituitary hormone.

Other Pituitary Hormones. Little is known of age changes in output of other pituitary hormones. Saxton and Loeb (1937) reported no noticeable diminution in thyrotropic secretion from maturity to the age of 90. Blumenthal (1951) substantiated this finding and, in addition, reported no age changes in ACTH output. Solomon and Shock (1950), who studied secretion rates of ACTH in young and old subjects, state that "the long-term output of ACTH is not notably reduced" in the older group. This lack of decrease in tropic-hormone secretion means that any decline in function of the gland on which the tropic substance acts must be due to changes in the gland per se rather than to decrease in the stimulating pituitary hormone.

Sex Glands

The sex glands, or gonads, include the female ovaries and the male testes. In addition to producing ova and sperms, respectively, the gonads secrete sex hormones. The ovaries produce the female sex hormones, *estrogens;* the testes, the male sex hormones, or *androgens*, the best known of which is *testosterone*, the so-called true male hormone. Estrogens and androgens are also secreted by the adrenal cortex in small quantities. Both hormone groups are thus found in both sexes, but both males and females have a large preponderance of the type peculiar to their own sex.

Although the X and Y chromosomes determine sex at the moment of fertilization, sex remains indistinguishable by either gross or microscopic examination for a number of weeks. It is only toward the end of the seventh week that sex glands become sufficiently differentiated to make possible distinction of the sex of the embryo. During both embryonic and early fetal periods, both ovaries and testes are located within the body. Sometime between the seventh and ninth months, the testes undergo what is known as an *external migration*, moving out through a canal parallel to the abdominal wall to descend into the scrotum. During childhood, the sex glands grow slowly and are functionally immature. Shortly before puberty, however, the increased output of gonadotropic hormones stimulates rapid growth and development.

Sex-hormone Output in Early Years. Androgens and estrogens have been detected in both sexes as early as the third year (Nathanson *et al.*, 1941; Oesting and Webster, 1938; and others). Most of the output in early years derives from the adrenal cortex, for the gonads are still immature. The studies of adrenal-tumor cases which result in precocious puberty even in very young children corroborate this belief. The early
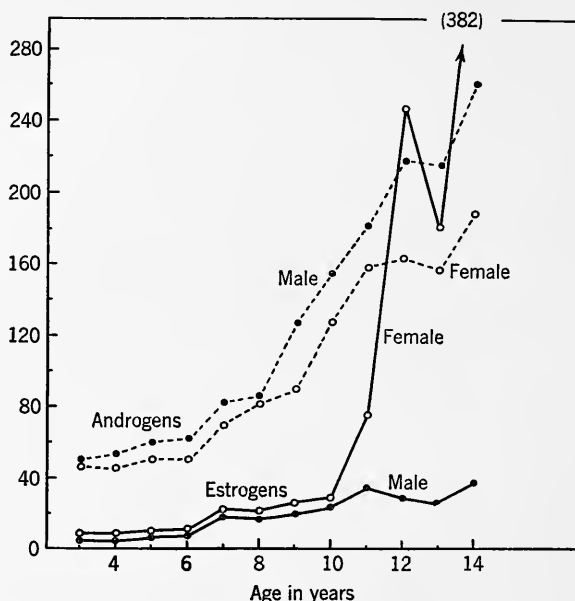

FIG. 29. Age changes in excretion of sex hormones during childhood. (*After Nathanson et al. From Shock, N. W. Physiological changes in adolescence. In 43d Yearb. Nat. Soc. Stud. Educ., Part I, 1944. P. 75. Quoted by permission of the Society.*)

androgen-estrogen output of children aged 3 to 14 years is illustrated graphically in Fig. 29.

From the age of 3 on, both boys and girls secrete a small but constant quantity of both androgens and estrogens, with slightly larger secretions of androgens by boys and estrogens by girls. The sex differences are not significant, however. From the age of 10 on, the androgen-estrogen ratio begins to diverge rapidly for the two sexes. This large increase of male or female hormones just before puberty is due to the increased activity of testes and ovaries, whose growth has been stimulated by gonadotropic hormones.

Effect on Reproductive Organs. Increases in sex hormones markedly affect the development of the reproductive organs. In the male, one of the most noticeable features is the increased size of the genitals. The testes, previously immature, now become capable of producing sperms.

As this ability develops, nocturnal emissions of semen become quite common and are frequently a source of anxiety to the growing boy.

In the female, the increased estrogen output results in enlargement of the external genitals; increased size of the ovaries, Fallopian tubes, and uterus; and development of the ovarian follicles, resulting in production of ova. The first menstruation, called the *menarche,* appears soon after these changes and signals the onset of puberty and the reproductive years.

Menstruation. Menstruation ushers in the period of puberty in girls. The age at which the first menstrual flow occurs varies for different individuals but usually takes place around the age of 13½ years. It is generally believed that the regular recurrence of the menstrual cycle is due to the rhythmic activity of the anterior pituitary, with its influence over ovarian hormones. During puberty, menstruation is frequently irregular but becomes stable once the cycle is well established. Regularity may be disrupted even in later years, however, by emotion-provoking situations. In males, no event analogous to menstruation occurs, and we have to rely on the appearance of secondary sex characteristics as criteria of maturity. On the average, boys mature later than girls, reaching puberty somewhere around the age of 14½ or 15 years. Individual differences are great for both sexes, however, with the range varying from 12 to beyond 17 years.

Secondary Sex Characteristics. During early childhood, there is little difference between boys and girls in height, weight, general body proportions, strength, skin texture, hair distribution, voice, or the many other characteristics that distinguish the sexes in adulthood. As a result of the differential hormone output, these features begin to appear shortly before puberty. They are known as *secondary sex characteristics.*

In the female, the earliest distinguishing feature is a broadening of the hips; this is followed by development of the breasts and growth of hair in various regions, especially of pubic hair in the genital area and axillary hair in the armpits. Voice changes and gradual coarsening of the skin can also be noted. Although all these changes begin before the menarche, they are by no means complete at that time.

In the male, skeletal proportions and bone structure also change. The shoulders become relatively broader than the hips; growth of hair on genitals, under armpits, and on the face follow roughly in that order. Voice changes are more conspicuous than in girls and are due to changes in the proportions of the vocal cords resulting in temporary loss of voluntary control over these organs. All these changes begin before the first production of sperms, but, again, are not complete at that time.

These more conspicuous physical changes are accompanied by certain other disturbing variations. The sweat glands of the armpits and genital regions enlarge, and their excretion rates markedly increase. Perspiration,

formerly odorless, now becomes more alkaline and takes on the character-
istic body odor which is particularly pronounced during late puberty.
The sebaceous glands that lubricate the skin become hyperactive, con-
tributing to oily skin and hair. If the ducts fail to keep pace with the
growth of the glands, the excretions may fail to drain properly and harden
in the pores to form pimples (acne) and blackheads. These body changes
cause considerable mental anguish to self-conscious adolescents, especially
to girls who aggravate them by attempts to remove or cover them with
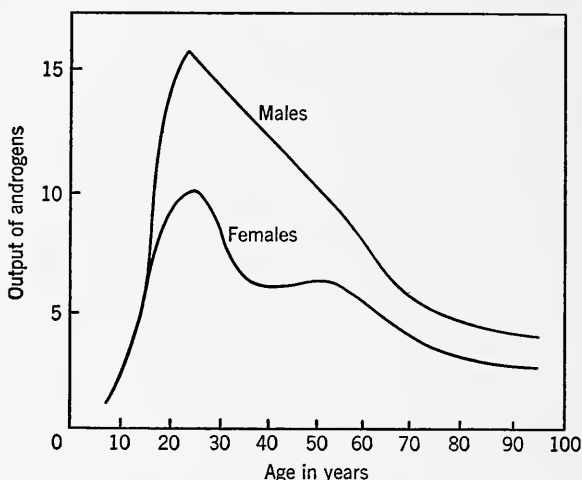
FIG. 30. Changes in excretion of androgens in males and females throughout the life
span. (*After Hamburger, C. Normal urinary excretion of neutral 17-ketosteroids with
special reference to age and sex variations. Acta endocrinol., 1948, 1, 31.*)

cosmetics and various other "beauty aids." Anxiety is also frequently
aroused by menstruation or by nocturnal emissions, especially in those
children who have received little or no sex education and hence do not
understand what is happening to them.

Effect of Sex Hormones on Phyone. The sex hormones serve another
important function in addition to bringing about sexual maturation. This
second function is the gradual inhibition of the growth hormone of the
pituitary, eventually bringing its influence to a stop and thus terminating
skeletal growth. If the gonads mature early, phyone production or its
effectiveness will be inhibited sooner and growth prematurely arrested.
On the other hand, late sexual development delays inhibition and the
growth period is thus extended. Skeletal growth is therefore dependent on
the carefully timed, reciprocal actions of the pituitary and gonadal hor-
mones (see Chapter 5).

Sex-hormone Output during Adolescence, Maturity, and Senescence.
We have so far been concerned only with prepubertal development of the

sex glands and its effect on growth. Let us now look at the androgen-estrogen output from puberty to old age.

Androgen Output. Hamburger (1948) studied the androgen level of 274 males and females ranging in age from childhood to senescence. His findings are illustrated in Fig. 30. Evidently there is no difference between androgen output of males and females prior to puberty. This is corroborated by the findings of Nathanson *et al.* (1941), shown in Fig. 29. After puberty, androgen output of males maintains a higher level than that of females at all age levels. The most interesting feature of Fig. 30 is that the peak of androgen secretion in both sexes is not achieved until the 20's, after which it immediately begins to decline and sex differences to decrease. Beyond the age of 50, androgen output of males and females again converges rapidly, although male output remains higher throughout life. It is interesting that androgen secretions in old age closely parallel output during the prepubertal period (compare Figs. 29 and 30).

Estrogen Output. Whereas androgen output shows a tendency to decrease in both sexes with advancing age, the course of estrogen output is quite different for the two sexes. Table 1, based on the work of Pincus and

TABLE 1. THE 24-HOUR URINARY EXCRETION OF ESTROGENS IN 237 MEN AND 253 WOMEN*

Age	Total estrogens, rat units per 24 hours	
	Men	Women
17–29	11.7	38.2
30–39	13.8	38.9
40–49	12.3	21.3
50–59	13.7	10.8
60–69	12.5	6.7
70–79	12.4	7.3
80–96	10.5	6.7

* From Kirk, J. E. Steroid hormones and aging: A review. *J. Geront.*, 1951, **6**, 255. Quoted by permission.

Kirk (Kirk, 1951), illustrates the age trends. Maximum secretion of estrogens occurs in the age interval 17 to 29 years in both sexes. In males, however, secretion shows no decline; the output for the youngest males (17 to 29 years) is approximately the same as for the oldest group (80 to 96 years). In females, the estrogen-output level is considerably higher than that of males during the reproductive years; after the menopause, it drops sharply to a level lower than that of males, and remains at this low level throughout the period 50 to 96 years. This abrupt drop in estrogen output around the menopause is in line with the earlier findings of

Pedersen-Bjergaard and Tønnesen (1948). Maintenance of estrogen level with advancing age, accompanied by a decline in androgen output in males, has been confirmed by Pincus *et al.* (1951).

Androgen-Estrogen Ratio. Since the estrogen output of males remains unchanged with advancing years, while androgen output decreases, the result is an interesting change in the androgen-estrogen ratios. From adulthood on, estrogens tend to show a relative predominance over androgens, as compared with the late pubertal and early adult ratios. This decline in androgen-estrogen ratio in males is shown in Table 2. By the age of

TABLE 2. THE ANDROGEN-ESTROGEN RATIO IN 204 MEN OF VARIOUS AGES*
(Personal communication from G. Pincus to J. E. Kirk)

Age	Androgen-Estrogen Ratio
17–29	13.9
30–39	10.9
40–49	
50–59	7.0
60–69	6.4
70–79	6.8
80–96	2.6

* From Kirk, J. E. Steroid hormones and aging: A review. *J. Geront.*, 1951, **6**, 256. Quoted by permission.

80, the ratio is roughly similar to what it was during the prepubertal period. Kirk (1951) interprets this as a possible "feminization" of males in later years and mentions such things as the slight development of breasts in older males. It is interesting to speculate whether these hormonal changes are related to the merging of earlier sex differences in interests and attitudes believed to occur in old age (see Fig. 106). Miles and Miles (1949), for example, in discussing interests and attitudes, state that a "marked trend inclines the men's decade scores toward the women's mean," and furthermore state that in senescence the male and female interests and attitudes are closer than at any other time of life after early childhood.

Effect on Reproductive Organs after Puberty. It has already been mentioned that the increasing androgen and estrogen outputs which occur shortly before puberty are responsible for growth in size of the sex glands and that secretions of these sex hormones continue to increase well into the 20's. Because of this, testes and ovaries also continue to grow beyond puberty. The testes reach adult size in the late teens or early 20's; the ovaries double their weight after puberty (Greulich *et al.*, 1938). Present data demonstrate clearly that adult gonadal activity does not mature at puberty, as is often suggested in textbooks, but at least a decade later.

It was formerly believed that the decline in sex-hormone output in later

years resulted from diminishing production of gonadotropic hormones. As we have noted, pituitary functions remain stable throughout life. We are therefore forced to look for an alternative explanation in the sex glands themselves. After surveying the literature, Kirk (1951) maintains that the primary cause of lowered androgen and estrogen output is the degenerative changes in testes and ovaries. The sharp drop in estrogen level in menopausal women coincides with a marked involution of the ovaries. Kirk believes that the lowered output may often be correlated with such psychological symptoms as moderate or mild mental depression, lack of energy, nervousness, tiredness, and hot flushes, in females; lack of energy, moderate mental depression, and reduced sexual activity, in males. According to Kirk, these symptoms may be alleviated by estrogen and testosterone therapy, especially estrogen therapy for menopausal women.

The menopause, whose arrival is signaled by the cessation of the menstrual flow, brings the reproductive period of the female to an end. What causes this is not known. Whatever the cause, sometime during the 40's (average age, 47) it comes to every female. Although reproductive functions end, sexual activity continues—indeed, several authorities believe that it increases once the fear of possible pregnancy is over. More will be said about this later. Many investigators—including the present authors —believe that the symptoms commonly attributed to the menopausal period have been overemphasized in our culture and are less common than publicity leads us to expect. Not long ago, an equal or even greater emphasis was placed on the "storm and stress" of adolescence; this idea was disproved—chiefly through anthropological studies which indicated an absence of emotional upheavals in adolescents of other societies. Although such studies are lacking on middle age, it is more than likely that a similarly exaggerated emphasis has been placed on the menopause—perhaps chiefly because of fears and anxieties concerning loss of sexual powers and desires as well as the high premium which our society places on the type of beauty peculiar to youth.

Sex Hormones and Sexual Activity. So far, nothing has been said about the role of sex hormones in sexual activity. In animals—especially of the lower phyla—sexual behavior is largely influenced and often determined by the sex-hormone level of the blood (see Morgan and Stellar, 1950). In human beings, however, there appears to be no such clear-cut relationship. Although removal of the sex glands prior to puberty will produce a loss in sexual desire, a similar operation after puberty does not always result in such loss, though reproductive ability is forfeited. Rössle (1935), who reported on 125 cases of adult males who had been castrated, states that only half of them showed any diminution in sexual activity. It has already been mentioned that postmenopausal women continue to engage in sexual activities. In discussing this problem, Morgan (1943) suggests

that social conventions and the setting up of habitual attitudes may be sufficient to maintain the desire for sexual relations and hence supplement or replace the basic hormonal determinants. In line with this suggestion, Beach (1947), after surveying the literature, concluded that as we ascend the phylogenetic scale sex hormones become less and less important in arousing sexual behavior, while the cerebral cortex becomes progressively more important. Thus, man, standing as he does at the top of the scale, is influenced most by the various nonhormonal stimuli (*e.g.*, habits, social conventions) in arousal and maintenance of sex activity.

Frequency of Sexual Activity. Let us next look at age changes in frequency of sex activity. The best available source on such data is Kinsey *et al.* (1948). According to Kinsey, sexual activity in the human male is at a maximum during the late teens and therefore fails to coincide with peak hormone output. Mean frequency per week of total sexual outlets for married males decreases from 4.67 in the late teens, through 3.27 in the late 20's and 1.79 in middle age, to 0.9 at age 60. The few cases available for ages beyond 60 indicate a further decline to 0.3 at 75 and 0.1 at 80. Thus, we find a progressive decrease from four or five times per week in the late teens to one outlet per three or four weeks at 75 and to three or four times per year at 80.

The range of variability also diminishes with age. The greatest frequency reported for the late teens was 25 outlets per week, as compared with a mean of 4.67. In old age, the population is relatively homogeneous with respect to frequency of sexual outlets. If Kinsey is right, sexual activity reaches a peak in the late teens and declines thereafter. In accounting for the declining frequency, Kinsey *et al.* include both physical factors, such as decreased hormone output and degeneration in muscles of the erectile tissues, and psychological factors, such as loss of interest in repetition of the same kind of experience and the exhaustion of the possibilities for exploring new techniques—in other words, lack of novelty or boredom.

Responsiveness to erotic stimulation also diminishes with age. Frequency of morning erections is highest around the age of 30—seemingly more closely parallel to peak hormone output than is frequency of intercourse. Impotence—that is, inability to attain or to sustain an erection—is rare during early life, occurring in only 0.4 per cent of males under the age of 25 and in less than 1 per cent under 35 years. The number of cases increases slowly at first and more rapidly after 55, so that by the seventieth year, 27 per cent of males are impotent; by the seventy-fifth year, 55 per cent; and by the age of 80, 75 per cent, according to Kinsey's data.

Sex-hormone Therapy. During the last few years, many investigators have been interested in the improvement of physical and psychological

capacities of the elderly by means of sex-hormone treatments. Current journals report several such studies. One of the most interesting experiments was done by Allen and Masters (1948), who studied the effect of estrogen administration on a group of females aged 64 to 82. By intermittently giving and withdrawing estrogen, they were able to elicit uterine bleeding which assumed the characteristics of the regular cyclic menstruation. The uterus itself showed various regenerative changes such as actual development of new blood vessels. With prolonged estrogen treatment, an increase in the size and firmness of the breasts was often noticed.

Testosterone therapy has been tried on elderly males. One of the interesting findings of such studies is that beard growth—a secondary sex characteristic—increases markedly (Chieffi, 1949). Attempts to improve sexual vigor have also been made. Kirk (1951) reports that this is occasionally successful and, when improvement occurs, it is thought to be due to an increase in tone and development of the erectile muscles of the penis. Kirk's findings are supported by Wainman and Shipounoff (1941), who observed that testosterone abolished atrophy of the muscles of the penis in rats.

While sexual potency has been improved only occasionally in human subjects, animal experiments have been more successful (see Morgan and Stellar, 1950). Minnick et al. (1946), for example, noted that senile rats which had almost ceased to copulate could be reactivated by doses of testosterone. Similar claims have been made for other animals. Such findings support Beach's view that sexual behavior of lower animals is controlled by gonadal hormones more than it is in man.

Sex-hormone therapy has also been found beneficial in rejuvenating the skin and the mucous membrane of the nose as well as in increasing muscular strength, memory, etc. (see Kirk, 1951). These studies will be reviewed in later chapters. After surveying the literature on sex-hormone therapy, Kirk concludes that "these findings cannot help but to introduce a certain amount of optimism into the science of gerontology. When atrophic changes, which until the last decade had been considered irreparable, have been demonstrated capable of restoration, the possibility exists that other organs may also be capable of some re-establishment of function, provided the adequate stimulus for such restoration is found." However, Kirk also adds a word of caution, pointing out that although the function of certain organs may be improved, the "uneven restitution of function may endanger the condition of the patient."

Other Endocrine Glands

In addition to the glands just discussed, three other glands—the pancreas, thymus, and pineal gland—also have endocrine functions. All

are of strictly vertebrate origin. Since they are not of great importance to growth and development, we shall look at them only briefly.

Pancreas. The pancreas has an endocrine function as well as a function in aiding the digestive process. Scattered throughout this gland are clusters of cells which secrete the hormone *insulin*. Insulin regulates the blood-sugar level of the body. According to Haist and Pugh (1948), the insulin content of the pancreas decreases in old age, but as the data are for rats only, it is unwise to generalize without more evidence on actual output in human subjects of various age levels.

Thymus. The thymus derives from the same embryonic tissues as the pancreas, thyroid, and parathyroids. It consists of the two lobes located in the region where the throat joins the chest. In young children it is quite large, but shrinkage begins around puberty, and by adulthood the thymus is much reduced in size (see Fig. 28). As yet, no hormone has been isolated from this gland. Some investigators believe that it stimulates growth and development; others think that it serves to inhibit premature sexual development. Research to date has given no definite answers regarding its function.

Pineal Gland. The pineal gland is a small oval structure located deep within the cerebral hemispheres. Not long ago, it was believed to be a vestigial organ of no particular value to human beings. Today, however, some interesting evidence of its function is being uncovered.

A number of investigators have suggested that the pineal gland is active up to the time of puberty and may be related to mental, skeletal, and sexual development (Martin, 1941). More recently, however, Borell and Örström (1947), using newer techniques involving radioactive isotopes on a number of different animals, made an unexpected finding: contrary to popular belief, the pineal gland showed greater activity in its shriveled state in old age than in the young animals. Furthermore, these investigators were able to demonstrate that it exerted a stimulating effect on the sexual organs (ovaries and uterus) of aged females. Unfortunately, this has not yet been corroborated for human beings.

PHYSICAL DEVELOPMENT

Whatever his age, the individual is a biological organism whose behavior depends largely on his physical make-up. Since physical changes occur continuously throughout the life span, it is important to understand them. Accordingly, this chapter will examine development in structure and function of various body systems. As we proceed we shall note the orderly sequence in which these changes occur, both with respect to size and proportions of the body as a whole and with respect to component parts such as the skeleton, muscles, or internal organs. These structural changes profoundly influence the intellectual, emotional, and personality characteristics of every individual.

CHANGES IN INTERNAL ORGANS

In the two preceding chapters, two important body systems—the neural and the glandular—were discussed. Although they rightly belong in the present chapter, they were treated separately because of their tremendous implications for behavior. Here we are concerned with the internal organs responsible for circulation, respiration, digestion, and excretion.

Circulatory System

Heart Action. The heart is divided into four chambers, two upper *auricles* and two lower *ventricles*. The heartbeat results from a rapid succession of events as the blood courses through these chambers. Auricles and then ventricles in turn contract, forcing the blood into the great vessels during the phase of activity known as the *systole*. The maximum pressure which results is accordingly called *systolic blood pressure*. Immediately following the rush of blood into the vessels, the heart relaxes momentarily. This second phase is the *diastole*, and hence the resultant minimal pressure is known as *diastolic blood pressure*. Normal systolic blood pressure for the normal young adult male approximates 120 mm. of mercury (120 mm. Hg); minimal or diastolic pressure is around 80 mm. Hg.

Changes in Heart and Arteries during Childhood, Adolescence, and Maturity. The heart begins to beat about 3 weeks after fertilization and continues its ceaseless task of pumping blood through the body as long as the individual lives. Cessation of activity means instant death. At some stages of growth the heart is forced to work harder than at others, however, for its work depends on such factors as its own size relative to the size of the arteries and to body length, which determines the distance that the blood must flow.

At birth, the heart is situated higher in the chest cavity and is heavier and larger in proportion to body size than at any other time of life. During preschool years, it grows rapidly, and by the age of 6 is four to five times as large as it was at birth. Growth rate then declines, remaining slow until puberty. At this time the heart is roughly seven times its birth size and is smaller relative to the body than at any other age. It has not yet completed its growth, however. Between puberty and the age of 17 or 18 years, it doubles both in weight and in volume. This increase is due almost entirely to changes in the number and size of its contractile muscle fibers.

Age Changes in Blood Pressure. At birth, blood pressure is very low, averaging only 40 mm. Hg (systolic). It rises quickly to a value of 80 mm. Hg by the end of the first month, and from this time onward it rises more gradually, attaining a value of 105 mm. Hg by the twelfth year (see Fig. 31). With the onset of puberty, growth rates increase generally. Blood pressure, too, rises more rapidly and reaches the normal adult level of 120 mm. during late adolescence (Best and Taylor, 1950).

Changes in Heart-Artery Ratio. The changes in blood pressure reflect the changes in ratio of heart size to blood vessels. At birth, both arteries and veins are large relative to heart size. Heart-artery ratio, for example, approximates 1.25:1. Thus the small heart pumps blood into relatively large channels for a short tour of a small body and meets little resistance. Blood pressure is therefore low. But arteries grow more slowly than the heart, and by puberty the heart-artery ratio has increased to 2.8:1. The larger heart now forces more blood into arteries relatively smaller in cross section for a longer journey through a larger body, and blood pressure of necessity increases. Between puberty and adulthood, the heart doubles in size, while the arteries increase in cross section by only 15 per cent, thus bringing the heart-artery ratio to a new high of 4.75:1 by adulthood. Accordingly, while physical growth has extended body dimensions and multiplied the peripheral blood vessels manifold, the cross section of the vessels remains relatively small, resulting in a rise in pressure. Figure 31 shows the changes in both systolic and diastolic blood pressures throughout the life span.

Once adult proportions have been achieved, blood pressure remains fairly constant for several decades. Between the ages of 20 and 60, systolic

pressure increases only slightly, from 120 to 135 mm. Hg—roughly a 15 mm. increment. These data fail to distinguish between sexes, however. Before the age of 10, there is little sex difference. During puberty and postpuberty, systolic pressure increases steadily in boys; in girls, on the other hand, systolic pressure increases to the fifteenth year, then declines to the eighteenth year when it slowly begins to rise again. This irregularity is thought to be related to the establishment of regular menstruation.
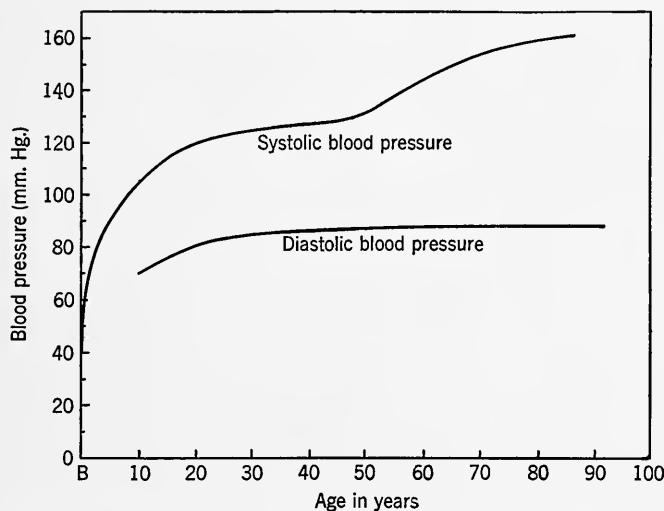
FIG. 31. Age changes in systolic and diastolic blood pressures in the male population ($N = 250,000$). Note the lack of increase in diastolic blood pressure in later life. (*Constructed from data of Best and Taylor*, 1950; *Russek and Zohman*, 1946.)

Interestingly, too, the systolic pressure in females remains 4 to 5 mm. Hg below that of males until the time of the menopause, when it rises to surpass male blood pressure and remains higher throughout the postmenopausal decades (Best and Taylor, 1950).

Heart and Blood Vessels during Later Maturity and Old Age. Figure 31 shows that systolic blood pressure increases noticeably after the age of 60. This increase results from various degenerative changes in the heart and blood vessels of the body.

The heart, perhaps the most important single organ of the body, undergoes some marked structural and functional changes in its later years. It increases in size and weight. The heart valves become less elastic and accumulate calcium deposits, with the result that they do not function so efficiently as they used to. The inner tissues of the heart thicken. Pigment appears in muscle cells, and the cross striations of the muscle cells diminish. *Electrocardiograms*, used to gauge heart activity, show decreased voltage and some slowing down of conduction efficiency On the whole, it

appears that the heart undergoes senescent changes similar to those already described for other organs (see Cowdry, 1942).

Arteries and veins are not exempt, either. Their walls lose their elasticity and thicken and harden through infiltration of calcium deposits and connective tissues. These structural changes appear to be more marked in the arteries serving the heart itself and the brain than in those serving other bodily organs (Gilbert, 1952). When all these changes are considered together, it is apparent that the aged heart tends to work less efficiently and that the blood encounters greater resistance in its passage through the blood vessels. Such a situation inevitably leads to heightened blood pressure.

Changes in Heart Rate. Heart rate, too, changes with age. At birth, this great pump beats about 130 times per minute. This rate decreases rapidly at first and then more slowly, until by the age of 10 it approximates 90 beats per minute in both boys and girls. There is great variability in heart rate among children, however, and even in the same child from time to time. Around puberty, sex differences emerge. During puberty, heart rate is often irregular, but generally speaking decreases in both sexes, finally stabilizing at an adult level of 72 beats per minute. There is some indication that heart rate increases again in old age, but the evidence to date is controversial. For example, Howell (1948) reports 76 beats per minute for a 60- to 64-year-old group, 69 beats for those aged 80 to 84, 73 beats for ages 85 to 89, and 79 beats for individuals aged 90 to 94. These data are far from conclusive, and more evidence is needed.

Exercise and Heart Rate. Some interesting work has been done on the effect of exercise on the heart rate of elderly people. Robinson (1938) reports that one of the characteristics of the aged is a lower acceleration of heart rate after strenuous exercise than in the young. Thus, a group of 14-year-old boys showed an average maximum rate of 196 beats per minute after exercise, while a group of older men whose average age was 65 showed a maximum rate of only 163 beats per minute—a difference of about 17 per cent. On the other hand, it has been demonstrated that following nonexhaustive exercise the increase in heart rate in aged subjects exceeds that of young controls (Master and Oppenheimer, 1929; Norris *et al.*, 1950).

Respiratory System

Rate of Breathing. Like heart rate, breathing rate is rapid at birth. During the first month of life, the infant breathes 34 to 45 times per minute. This rapid rate decreases quickly, and by the end of the first year has dropped 10 points to equal 25 to 35 inspirations per minute. The average range for years 1 to 6 is 20 to 30 inspirations; for the 6- to 10-year-olds,

18 to 25; and for children over 10, 16 to 20. This is the normal adult rate. Thus, the rapid, shallow breathing of the infant is gradually replaced by the slower, deeper respiration of the adult.

Changes in breathing rate are due chiefly to the increase in size of the respiratory organs and to added elastic tissues. At birth, the lungs are small. This becomes clear when we see that the chest circumference of the newborn baby is smaller than his head circumference. The proportion changes as the child grows. At 2 years, chest and head circumferences are equal; at 15, chest circumference exceeds head circumference by 50 per cent; and in adulthood, by 67 per cent. As the chest cavity increases in depth and width, the lungs and accessory structures grow rapidly.

Changes in Lung Capacity. Developmental changes in the respiratory organs are reflected not only in decelerated and deeper breathing but also in changing air capacity of the lungs. To determine lung capacity, investigators usually take three measurements: vital capacity, residual-air capacity, and maximum breathing capacity. *Vital capacity*, the most commonly studied, is a measure of the maximum amount of air which can be breathed out after taking the deepest breath possible. The air left in the lungs after such deep breathing in and out is known as *residual air*. Finally, the *maximum breathing capacity* (MBC) is a measure of the largest quantity of air which can be moved in and out of the lungs over a period of time.

It is difficult to take such measurements with very young children. Studies of 4-year-olds indicate a vital capacity of about 800 cc. of air. This gradually increases during childhood to reach a value of 2,600 cc. by the time of puberty (Stewart, 1922). Prior to puberty, sex differences are slight, although the average boy tends to have a greater vital capacity than the average girl. From this time on, however, the curves for vital capacity diverge farther and farther for the sexes, although both continue to rise. Girls attain adult capacity of 3,000 cc. sometime around the age of 17; boys achieve adult capacity of 4,000 cc. several years later.

Sex differences in vital capacity are undoubtedly due to differential lung development in terms of size and capacity. In this boys have a decided advantage, as will be seen later in the discussion of skeletal growth. The greater amount of physical activity and exercise which boys engage in may also be a factor.

Respiratory Changes in Later Years. Vital capacity, which reaches a peak sometime during late adolescence, shows no appreciable drop until after the age of 50. From this time on there is a gradual decrease, reaching 50 per cent of adult value by the age of 85. The greatest decline occurs between the ages of 50 and 60 years (Bowen, 1923). Scores of various age groups overlap considerably, and frequently elderly subjects have high vital-capacity

values. Several variables seem to influence the rate and amount of decline. Individuals who remain physically active, for example, show less decline than those who are sedentary (Kaltreider *et al.*, 1938).

Age changes in the three measures of lung capacity described earlier are shown in Table 3. In line with what has already been said, it can now be noted that the vital capacities of both males and females remain constant during early maturity but decrease after the age of 50. On the other hand, maximum breathing capacity begins to decline during the early 30's, and the decline is especially noticeable in males. This earlier decline may be related to the greater complexity of the latter measurements, for maximum breathing capacity depends not only on the normal elasticity of the various respiratory tissues but also on neuromuscular coordination of chest movements, which plays only a minimal role in measuring vital capacity. As was noted in an earlier chapter, the neural structures concerned with coordination of movements begin to deteriorate quite early.

TABLE 3. AGE CHANGES IN VITAL AND MAXIMUM BREATHING CAPACITIES*

Function	16–34		35–49		50–69	
	Female	Male	Female	Male	Female	Male
Vital capacity, supine in cc.	2,312–4,150	2,792–4,950	2,212–3,435	3,300–5,240	1,570–3,525	2,184–5,429
Average................	3,057	4,012	2,830	4,160	2,431	3,417
Residual air / Total capacity	20.0		23.4		30.8	
Standing MBC, liters/min.	93.7	126	89.3	109.4	73.5	90.6

* Based on data of Baldwin, E. F., Courand, A., and Richards, D. W., Sr. Pulmonary insufficiency I. Physiological classification, clinical methods of analysis, standard values in normal subjects. *Medicine, Baltimore*, 1948, **27**, 243.

Of particular behavioral significance are the age changes in ratio of residual air to total lung capacity depicted in Table 3. As we advance from early maturity to old age, the amount of residual air with its high carbon dioxide content comprises a larger and larger fraction of the total lung capacity (increases from 20 to 30.8 per cent). In practical terms, this means that the oxygen and carbon dioxide exchange becomes less efficient in the later years; less oxygen is taken into the lungs and more carbon dioxide left behind. This may be expected to affect particularly the recovery rate after strenuous exercise or during heavy work of extended duration. Coupled with decreasing efficiency of the circulatory and skeletal-muscular systems and with neural deterioration (*e.g.*, pyramidal tract and cerebellum), it makes for a decrease in ability to endure sustained effort with advancing years.

Structural Changes in Later Years. The functional changes just discussed are without doubt due to structural changes in the respiratory organs of the elderly. Many of these changes parallel those which have already been mentioned for other organs. The lungs decrease in size and weight. The mean weight of the two lungs of persons aged 65 to 85 is about 1,000 grams; for those aged 85 to 90, about 900 grams. Elasticity of lung tissues also decreases. In contrast to the yellowish pink color of the normal adult's lungs, those of the aged are reported to be gray with dark "splotches" throughout the tissues. This color change may not be entirely due to aging, however, but to an accumulation of various particles inhaled through the years (see Bickermann, 1952).

In addition to changes of the lungs themselves, the respiratory passages show cellular loss, increase in connective tissue, and impaired circulation. Structural changes in the bones and muscles of the chest limit ability to expand and contract this structure. Collectively, these structural changes account for the impaired lung activity of the elderly.

Digestive System

Development of the digestive tract is closely related to growth in general, for food supplies the building materials for all tissues. Nature has anticipated this, and the smooth muscles essential to digestive activity are far more advanced at birth than the skeletal muscles associated with motor behavior. Interestingly, too, skeletal muscles may deteriorate with advancing years, but few changes are evident in the smooth musculature (see Häggqvist, 1931; Gilbert, 1952). As far as structure is concerned, smooth muscles evidently continue to function efficiently throughout life.

Changes during Infancy and Childhood. At birth, the stomach holds 1 oz. Its rapid growth becomes evident when we note that at the end of the second week it accomodates 2½ oz. and at the end of the first month 3 oz. The neonate's stomach is tube-shaped as contrasted with the pouchlike, J-shaped structure of most adults, and is located in a transverse rather than an oblique or vertical position. This means that it empties more quickly, especially if the infant lies on his right side. The lining of the whole alimentary tract is more delicate than in the older child or adult, and digestive juices are produced in smaller quantities. Coupled with a complete absence of teeth, this makes careful choice of liquid foods and frequent feeding necessary. In view of the extremely rapid growth of the first year of life, the infant needs more calories per unit of body weight than at any subsequent time. If we consider the smallness of the stomach, its transverse position, and the great demand for calories, it is not strange that the infants schedule should be such a monotonous repetition of "feed and change,"

Toward the end of the first year, the infant's stomach approximates ¼

its adult size. Glandular activity increases; acidity, for example, is also $\frac{1}{4}$ as high as the adult value. Intestines grow in length and cross section, becoming more coiled. The small intestines of the infant are roughly 340 cm. long as compared with 760 cm. in adulthood. At 1 year, the infant's stomach evacuates 100 to 150 grams of milk in 1.5 to 3 hr., while the adult stomach empties 4 times this quantity in 2 to 3 hr.

Muscular Contractions. While ingesting food is a new experience for the neonate, the stomach is nevertheless ready to cope with its new task. Stomach contractions have been reported prior to the initial entrance of food into the stomach after birth (Carlson and Ginsburg, 1915). As the smooth muscles become thicker, these early contractions increase in strength and deepen into peristaltic waves. Such waves have been observed at 3 months. Carlson (1916) found that the stomach of the infant manifests greater hunger motility than that of the adult. The period of quiescence for the infant is 10 to 60 min., in contrast to the 1 to 3 hr. of adults.

Changes during Adolescence. Prior to puberty, the shape and position of the stomach tends to vary widely for different individuals. The postpuberty stomach is characterized by a J shape. Sex differences in the location of the stomach also emerge after puberty, the female stomach being located somewhat lower in the body. Apart from changes in shape and location, the stomach of adolescents increases greatly in size. The esophagus, too, grows in size and the intestines in length and diameter.

Food Requirements. Because of the physical growth spurt which begins around puberty, the teen-ager needs considerably more food than he did during middle childhood. Coupled with this demand, the increasing size of the digestive apparatus and the increasing glandular activity lead to the tremendous craving for food with which most mothers are familiar. Adolescents often consume twice as much food as the average manual worker. Calorie intakes of 3000 to 5000 are not unusual.

Digestive Disturbances. Difficulties in digesting food are common during adolescence. One extensive study reported that over 50 per cent of all adolescent boys and girls complained of digestive disturbances such as vomiting or nausea (see Garrison, 1951). Although the causes of such upsets vary, they are usually (1) excessive intake of food, (2) poorly balanced diet with an excess of fats and carbohydrates, (3) irregular eating habits, and (4) vitamin or calcium deficiency. These factors also aggravate the skin eruptions prevalent at this time and may induce anemia.

Changes in Old Age. The digestive system wears well with age. As was mentioned earlier, smooth muscles, comprising a large part of the digestive tract, appear to undergo few, if any, degenerative changes. Such absence of atrophy does not apply to all structures concerned in digestion. The glands of the mouth which secrete saliva and the enzyme ptyalin

that breaks down starches do deteriorate. So do the stomach glands, secretors of the enzymes which act on starches and proteins. Interestingly, the pancreatic glands show little, if any, secretory diminution. Thus, although digestion of food may be impaired during its early stages in the mouth and stomach, it may be carried to completion at the lower pancreatic level (see Chapter 4 for more detail). It appears, therefore, that older people are physiologically capable of adequately digesting either starches, fats, or proteins.

As we have already noted, the periods of quiescence of stomach contractions are brief in infancy, often lasting only 10 min. or so, whereas in adulthood they may extend to an hour or more. With advancing years, these periods become longer, and the period of active stomach contractions tends to shorten and become more feeble. It has been claimed, however, that "this evidence of impairment of gastric activity is insufficient to cause significant delay of the emptying time of the stomach, and is not significant enough to produce impairment of digestion" (Carlson, 1949).

Although the digestive system wears well with age, gastric complaints are exceedingly common among elderly people—indeed, digestive symptoms are among the most common of all the complaints of the aged. Since the digestive system is highly susceptible to emotional disturbances, it is quite likely that worries and anxieties play an important role in bringing about such symptoms. Disease and abuse of the digestive apparatus are other likely factors.

Excretory System

Wastes must be removed before their toxic influence poisons the body. Solid wastes pass directly through the alimentary canal, while liquids are excreted through the kidneys in the form of urine or through the pores of the skin.

Frequency of Excretion. Both the rapid turnover of liquid foods in the infant's stomach and the relatively short and straight intestines are conducive to frequent waste excretion. Defecations number 4 or 5 per day during the early weeks of life, while urine is voided 18 or 19 times daily. Growth of the alimentary tract, changes in the size and shape of the stomach, coiling of the intestines, and increasing proportions of solid food soon reduce elimination frequency, and by the end of the first year an adult level of one defecation per day is achieved by most children. Studies of adults reveal that 96 per cent of all males and 92 per cent of females follow this daily routine (Walsh *et al.*, cited in Ivy and Grossman, 1952).

Constipation is one of the most common complaints of the aged. Factually, there is little basis for thinking that it is more common in old age than in adulthood. A comparison of 1,000 college students and 824 people

over the age of 80 indicated that roughly 31 per cent of each group complained of constipation (see Gilbert, 1952). Nevertheless, like the digestive system, the excretory apparatus is sensitive to emotional and other disturbances. Probably Josh Billings had a good point when he stated, "I have kum tu the konklusion that a good reliable sett of bowels is worth more tu a man than enny quantity of brains."

CHANGES IN SKIN

Apart from changes of height and weight, perhaps the most easily observable of all physical changes occur in the skin. The soft, transparent skin of the child becomes thicker and coarser as he approaches puberty, and the pinkish "flush of youth" gives way to increasing sallowness. The soft, downy covering of the child's skin grows heavier and is supplemented with coarser hair in such regions as the armpits and around the genitals. In boys, facial hair is replaced by beard growth at the time of puberty. The changes of later life are familiar to all of us. The skin becomes dry and wrinkled as elasticity and regenerative capacity decrease; hair turns gray, and baldness is common. During the last few years, investigators have devoted considerable time and attention to studies of the aging of the skin. Let us look briefly at some of their findings.

Regenerative Capacity of Skin. As age creeps on, skin injuries heal more and more slowly. In a 20-year-old person, a skin wound of 40 sq. cm. heals completely in 40 days. A skin wound of similar size in a 40-year-old requires 80 days, while in an 80-year-old a similar wound takes roughly five times as long to heal as in a 10-year-old child (Carlson, 1949).

Elasticity of Skin. Decreases in the regenerative capacity of the skin are paralleled by degenerative changes in tissue fibers. In older people, the tissue fibers tend to become thinner, to split, and to decrease in number. Such changes are especially marked in the upper layers of the skin (Ma and Cowdry, 1950).

That such structural changes should be reflected in decreasing elasticity is logical and has been demonstrated experimentally. The elasticity of skin and subcutaneous tissue over the tibia have been compared for young controls aged 18 to 25 years and older subjects aged 60 to 80. Comparison revealed poorer elasticity in the older group. In addition, the elderly showed no difference in skin elasticity before and after a day of physical activity, although such a difference is normal in younger subjects (Kirk and Kvorning, 1949).

Wrinkling of the Skin. One aspect of aging which contributes in no mean degree to the dread with which many people face the inevitable later years is deterioration in appearance resulting from skin changes, specifically about the face and neck. These changes are especially feared by people of

the entertainment world whose livelihood depends on a youthful appearance. With the high premium placed on male physique and female beauty in our culture, however, they are only slightly less important to most of the fair sex of our society.

Wrinkles are not only skin deep. The contraction of certain underlying muscle groups causes repeated creasing of the skin, eventually leading to permanent lines or wrinkles—in popular parlance called "character lines," perhaps with some justification. Facial wrinkles are the result of repeated contractions of the intrinsic facial muscles. Wrinkles of the neck are caused by the activity of skeletal muscles concerned with head and neck
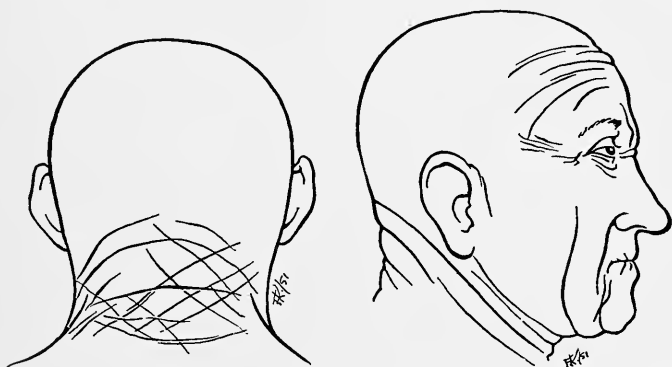
FIG. 32. Pattern of skin wrinkling in old age. (*From Chieffi, M. Cosmetological aspects of ageing. In A. I. Lansing (Ed.), Problems of ageing. Baltimore: Williams & Wilkins, 1952. P. 911. By permission of the publishers.*)

movements. Decrease of skin elasticity, diminishing quantities of subcutaneous fat, and lessening of gland secretions also play a part.

Time of Appearance. The various wrinkles, or character lines, of the face and neck appear in a fairly definite sequence. As might be anticipated, individual differences are great; nevertheless, certain general trends emerge. During adolescence or even earlier, one or more horizontal lines begin to appear at the front of the neck. As age advances, these lines are prolonged laterally and upward. Around the third decade, lines begin at the side of the neck, becoming more clearly marked during the fourth decade. Lines emerge at the back of the neck during the fourth and fifth decades. These vary in number, and generally crisscross to give a diamond pattern. These creases are clearly shown in Fig. 32.

The face is normally clear and unlined during youth, usually until the middle 20's. First to appear are the lines across the forehead and next those at the root of the nose. Lines around the eyes are uncommon until the fourth decade, while radiating lines around the mouth emerge sometime during the 40's. In later years, the loss of subcutaneous tissues becomes more and more prominent, and, as skin elasticity decreases, the

skin droops to hang loosely in coarse folds. Finally, as the bones begin to atrophy and as teeth are lost, the facial contours become distorted (Chieffi, 1952).

Histological examination of the wrinkled surfaces reveals that, except in youth, the lines are not mere infoldings of the skin but are accompanied by definite structural changes. These changes consist of decreases in the number of cell layers, changes in the nuclei, and alterations in elasticity and vascularity of the tissues, beginning in early adulthood and increasing with age. Changes are always more noticeable in wrinkled regions than in surrounding areas (Vollarelli, 1920).

Endocrine Therapy and Aging of Skin. Throughout the history of mankind, salesmen have successfully exploited every conceivable device for retarding aging of the skin. A few years ago, advertisements recommended facial massages and lanolin and various other oils. Since World War II, the trend has turned toward creams containing sex hormones. Interestingly, some dramatic regenerative changes have been observed following administration of certain sex hormones to the aging skin. In two such studies, androgenic and estrogenic hormones were applied to the skin over a period of time. Skin sections were subsequently cut out and examined microscopically. If sufficiently large doses of the hormone solution were used, regenerative changes such as an increase in the number of cell layers and in vascular supply resulted. This effect was noted in both sexes (M. Goldzieher, 1946; J. Goldzieher, 1949).

Some excellently controlled quantitative experiments on skin elasticity in old age have been reported (Chieffi, 1950a, 1950b). In these experiments, sex hormones in oil solution were applied to an area of skin on one side of the body while oil only was rubbed into a comparable area on the other side. Massaging the skin of either male or female with estrogen in oil solution increased skin elasticity significantly. Administration of testosterone to male skin was without effect. Data are lacking as yet on the effect of male-hormone applications to female skin.

These studies indicate that certain regenerative skin changes may result from topical application of sex hormones. One wonders about the longterm effects of such treatments, however. Face-cream manufacturers have been prompt to exploit the findings, and almost every cosmetic brand currently has an estrogen cream on the market. Whether these creams possess a sufficient concentration of sex hormones to do any good is an open question. If these findings are substantiated, the best one can hope is to delay the onset of wrinkles. Once character lines are fully developed, the only recourse is *rhytidectomy*—that is, plastic surgery through which wrinkles are removed by traction on the skin—and even such drastic measures are only temporary.

CHANGES IN HEIGHT AND WEIGHT

So far, we have been concerned almost exclusively with physical development and decline difficult to see. Now we come to the most readily observable of all physical changes—changes in height and weight. Height and weight have been extensively studied over a period of half a century, and the resulting data have formed many bulky volumes. Only a brief summary will be included here, since more comprehensive treatment is available in any contemporary text on child or adolescent development.
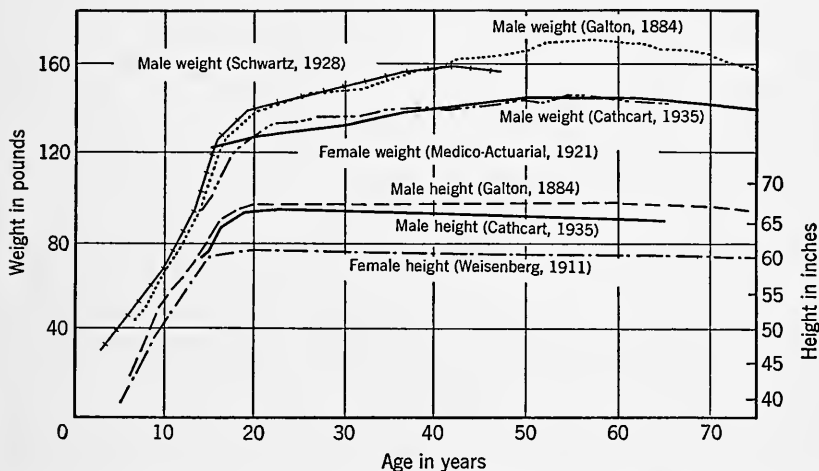
FIG. 33. Changes in average height and weight with age. (*From Pressey, S. L., Janney, J. E., and Kuhlen, R. G. Life: a psychological survey. New York: Harper, 1939. P. 126. By permission of the publishers.*)

Changes in Height during Life Span. At birth, the average infant measures 19 to 20 in. in length. Growth is rapid, and by the first birthday he is 27 to 29 in. tall, and by the age of 6, about 40 in. The average height of the American adult male is 67 in.; of the female, 64 in. Mature stature is attained by the late teens. From this time on, height remains fairly constant until late maturity, when it begins to diminish. This slight decrease during the later years is due to shrinkage of cartilage and ligaments at the joints and to loss of muscle tonus, reflected in posture. There is no loss of bone length. The age changes in height are graphically illustrated in Fig. 33.

Height depends on a number of factors. One of the variables is ethnic origin. In general, children of North European stock tend to be taller than South European children. This difference appears in measurements made at birth. Nevertheless, differences may also be due to nutritional or related socioeconomic factors. Japanese children reared in the United States,

for example, are taller than Japanese boys and girls reared in Japan. Another interesting finding, probably related to socioeconomic factors, is that children of laborers average $\frac{3}{4}$ in. shorter than those of professional groups (Meredith, 1941).

Growth Spurts in Height. An important aspect of growth not shown in Fig. 33 is the variability in growth rates from year to year during childhood. These variations are clarified by Fig. 34., in which height increments
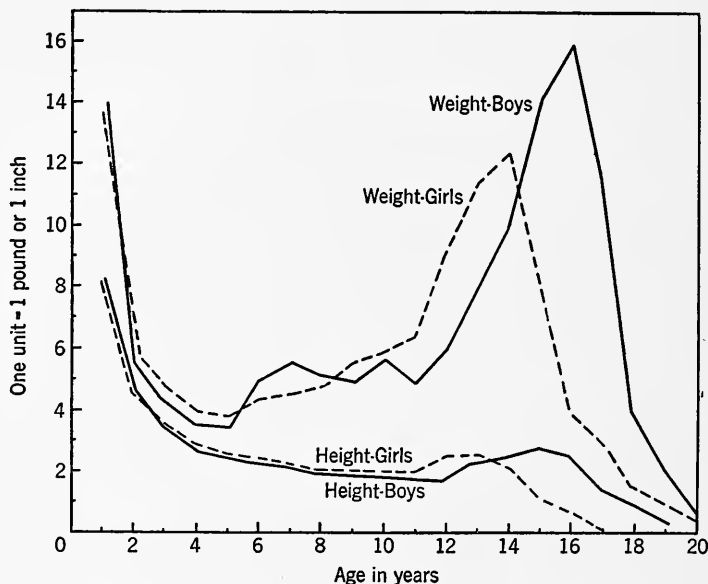
Fig. 34. Average increments each year in height and weight. (*After Pfuhl. From Pressey, S. L., Janney, J. E., and Kuhlen, R. G. Life: a psychological survey. New York: Harper, 1939. P. 127. By permission of the publishers.*)

are plotted against age. Apart from the extremely rapid growth during prenatal life, height increments are most conspicuous during the first 2 years and just prior to puberty. Girls reach the prepubertal growth spurt at the age of about 11 or 12, a year or two earlier than boys. Although boys are slower starters, they surpass the girls by the fourteenth or fifteenth year, growing several inches taller and retaining that superiority throughout life. According to Fig. 34, girls show the greatest increments during the twelfth and thirteenth years; boys during the fourteenth to sixteenth years.

Individual Differences in Growth Spurts. If growth curves of individual children are compared, it will be seen that many do not conform to the averages discussed above. This applies to both boys and girls. The early-developing child may reach the growth spurt a year or more before the average, while the later developers may lag behind.

Individual differences are shown in Fig. 35, which records separately the growth curves of nine girls (designated A, B, etc). Prior to the tenth year, all the curves are parallel, indicating that all girls are growing at similar rates, although A is taller than I, for example. A is an early-maturing girl, however, whose maximum growth spurt occurs at 10.5 years (ages of
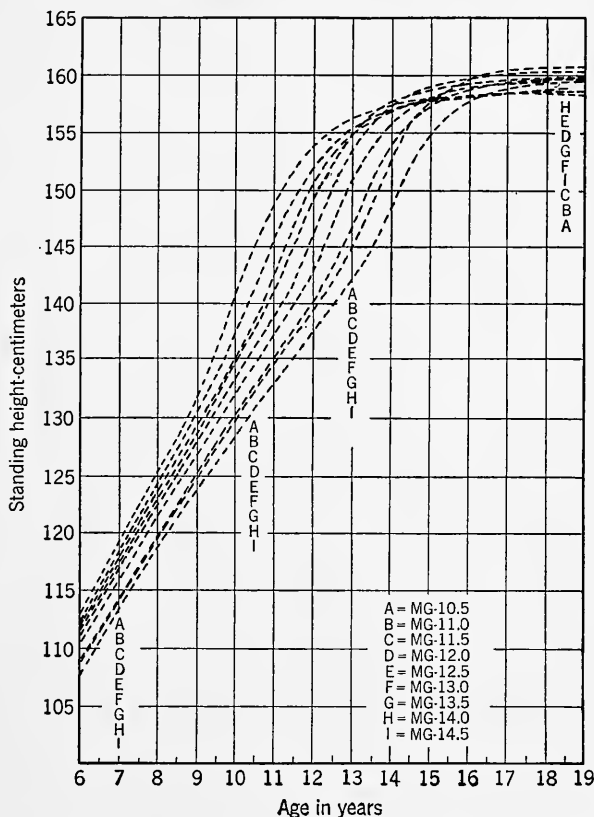
FIG. 35. Growth trends as related to age at maximum growth (girls). (*After Shuttleworth. From Greulich, W. W. Physical changes in adolescence. In 43d Yearb. Nat. Soc. Stud. Educ., Part I, 1944. P._13. Quoted by permission of the Society.*)

maximum growth are noted in the lower right corner of the graph). At 13, A has reached adult stature. Girl I, on the other hand, is the latest maturer of the group. She does not reach her growth spurt until the age of 14.5 years and does not achieve adult stature until the late teens, when she is taller than A. The other seven girls are intermediate in time of development and therefore approximate the average more closely. Figure 35 shows clearly the great differences in height during the 10- to 15-year interval. The vertically placed letters A to I indicate the respective heights of the

girls at various ages. At 10 and 13 years, A is taller than B, B is taller than C, etc. At maturity, the order has been changed so that A is the shortest of the group while I holds an intermediate position.

It has often been suggested that early maturers tend to be shorter than late maturers. The reason given is that the late maturers have a longer growing period before the diaphyses finally fuse with the epiphyses to stop growth (see explanation, page 118). This suggestion is still open to question. Skeletal X rays provide a safer basis for prediction.

Individual differences among boys form a similar picture. Since boys tend to be taller than girls, even greater variability is possible.

The average child has few problems related to growth in height. Deviates, either early or late maturers or those who deviate permanently, may have problems related to height. The early maturer may be tall and accordingly conspicuous among his classmates. Since changes in other physical characteristics accompany increase in height, an extremely early maturer may well feel ill at ease in a group of youngsters who continue to look (and act) like children. The late maturer continues to be a child among classmates who have suddenly become strange young men and women. Explanations of growth rates will serve to alleviate the problems, since they cannot be removed.

Changes in Weight during Life Span. In addition to height, Fig. 33 illustrates weight changes throughout the life span. The average infant weighs between 6 and 8 lb. at birth. As a rule, girls weigh slightly less than boys. Like height, weight increases rapidly during the growing years, and their respective growth curves parallel each other into adolescence. Beyond the age of 20, the height and weight curves gradually diverge, however. While height remains constant for a number of decades, weight increases to the middle 50's and declines several decades later. This ultimate decrease is caused by loss of tissue fluids and by other chemical changes associated with old age.

Growth Spurts in Weight. Rate of growth in weight also varies during the first 20 years of life. Figure 34 indicates that, like height, weight shows two major growth spurts—one during the first 2 years and the second around puberty. The circumpubertal weight spurt for both boys and girls lags a year or two behind the height spurt. Thus, maximum increase in weight occurs during the thirteenth and fourteenth years for girls and at least a year later for boys. Individual differences are similar to, and just as great as, those for height.

BODY PROPORTIONS

Changes in height and weight give only a general impression of development, for body proportions also change with the years. These are well

illustrated by the line drawings shown in Fig. 36. An examination of the drawings will reveal that some body parts achieve mature size at one age while other parts may do so either earlier or later. It is a common saying that, between birth and adulthood, "the head doubles, the trunk triples, the arms quadruple, and the legs quintuple their length." As we shall see, this is approximately correct.

Head and Face. The newborn infant is "top-heavy." At birth, his head comprises roughly ¼ of his body length (22 per cent). While the head doubles between birth and adulthood, the total body length increases 3.5

| 2 months | 6 months | Newborn | 2 years | 6 years | 12 years | Adult | Old man |
| (fetal) | (fetal) | | | | | | |
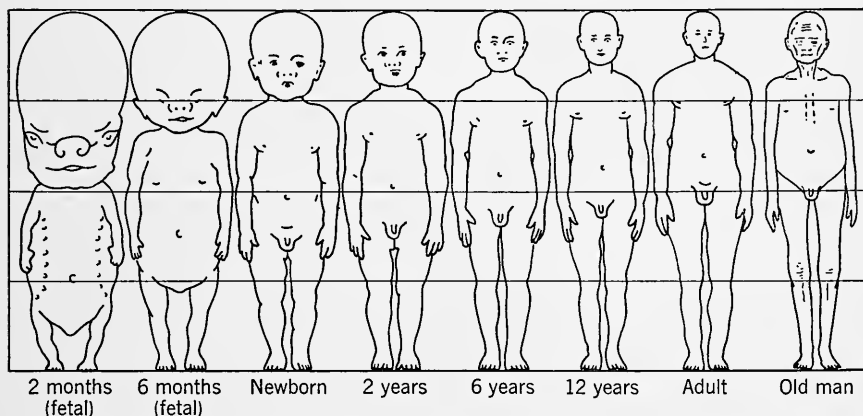
FIG. 36. Changes in body proportions with age. All figures are of the same height in order to facilitate comparison of age changes in bodily proportions. (*From R. E. Scammon in Morris, Human anatomy.* (*6th Ed.*) *New York: Blakiston; and Pressey, S. L., Janney, J. E., and Kuhlen, R. G. Life: a pyschological survey. New York: Harper, P.* 135. *By permission of the publishers.*)

times, thus reducing the head-body ratio as age advances. Even the proportions of the head itself change. At birth, the face-cranium ratio is 1:8; at 5 years, 1:5; by adulthood, 1:2.5. Thus the face, and especially the jaws, become more prominent, while the cranium increases little in height. The relatively large cranium, small face with rounded forehead, small flat nose, tiny chin, and large eyes give the infant the familiar "baby look," which disappears as proportions change and contours become more angular.

The nose is the most interesting facial feature, as far as growth is concerned. It is small and flat at birth, but it grows rapidly and matures earlier than other body parts, thus temporarily distorting facial proportions. This early growth is apt to distress adolescents who view themselves as veritable Cyrano de Bergeracs.

Trunk. The top-heavy infant has a disproportionately large trunk as well as head. While the head alone comprises 22 per cent of the body length, the trunk makes up between 40 and 50 per cent; the retarded legs,

which account for half of our adult height, contribute a mere 30 per cent in infancy. During the preschool years, the trunk doubles in both length and thickness. This rapid growth rate then decreases, so that by adulthood the trunk is only 3 times as long and 2.5 times as thick as at birth.

Proportions of the trunk itself change most rapidly around puberty. Before that time both boys and girls have triangular-shaped chests, with the broad base of the triangle along the back and the apex at the front. At puberty the chest expands to become more square than triangular. In girls, hip width (*bi-iliac diameter*) increases, while in boys hips remain relatively slight, and shoulder width (*biacromial diameter*) increases. Both boys and girls develop waistlines at puberty as a result of the shifting shoulder and hip proportions.

The top-heavy child finds it difficult to balance on short legs even when the bones have become sufficiently calcified to support him. Boys frequently learn to walk later than girls because of their greater weight; a heavy child of either sex tends to walk later than a slight child. With changing body proportions, the center of gravity shifts, making for better balance and more fluent motion. Muscle coordination is an important factor. Nevertheless, the short, stocky individual is less graceful in execution of movements at any age, since longer and "better" proportional limbs provide better leverage.

Limbs. Since we have already noted the contribution of leg length to height, we shall confine ourselves to the extremities—hands and feet. The hands and feet grow rapidly during the first 2 years, then more slowly, and mature at puberty. During the periods of rapid growth, a child easily outgrows a shoe size in a month or two. At puberty, when the feet have reached adult size before many other body parts, they may seem unduly large. Girls, especially, may attempt to compensate by forcing the feet into shoes too short or too narrow. Short shoes force the bones out of position, resulting in bunions at the joints. This problem would be avoided if the young adolescent understood something about differential growth rates and knew that the disproportion was only temporary.

Body Proportions in Later Years. The changes that can and do occur in older people are shown in Fig. 36. Most conspicuous are the facial changes. As facial muscles and overlying skin begin to sag and as the jaws collapse, the chin becomes unduly prominent. Loss of tissues and muscle tonus again gives the face a flattened look. Changes in other body parts include sagging shoulders, shrunken chest and abdomen, and shrunken limbs. Posture is frequently poor.

PHYSICAL MEASUREMENTS

Not many years ago, the teacher or school nurse lined children up with backs to the classroom wall and noted their heights on a chart tacked to

the paneling. Next, each child stepped on a scale and weight was noted. It was a simple matter to compare individuals with norms, one set for each sex, and to classify them as "underweight" or "overweight." Today, life is no longer so simple. Anthropometrics, the name given to physical measurements, has become a science in its own right and is certainly not the peculiar prerogative of physical anthropologists, as is so commonly believed.

Measure					Case F-9 early maturing boy
C. A.	11.3	13.7	15.7	17.2	
Weight (lbs)	104.9	134.7	141.3	150.8	
Height (in.)	60.6	68.0	71.1	71.5	
Stem length	31.1	34.5	36.8	37.0	
Bi-iliac	9.8	11.0	11.4	11.6	
Biacromial	12.7	14.0	15.0	15.7	
$\frac{\text{Stem length}}{\text{Height}}$	.514	.508	.519	.518	
$\frac{\text{Bi-iliac}}{\text{Height}}$	.161	.162	.160	.163	
$\frac{\text{Bi-iliac}}{\text{Biacromial}}$	.787	.787	.758	.741	

Measure					Case E-12 late maturing boy
C. A.	11.6	13.6	15.6	17.1	
Weight (lbs)	79.6	93.0	120.8	140.6	
Height (in.)	58.0	61.6	67.9	72.0	
Stem length	28.3	29.7	33.0	35.9	
Bi-iliac	8.9	9.6	10.4	11.0	
Biacromial	12.0	12.6	13.9	15.3	
$\frac{\text{Stem length}}{\text{Height}}$	.489	.483	.485	.499	
$\frac{\text{Bi-iliac}}{\text{Height}}$	.156	.155	.155	.153	
$\frac{\text{Bi-iliac}}{\text{Biacromial}}$	.756	.758	.752	.745	

FIG. 37. Bodily changes with increasing age in an early- and in a late-maturing boy. (*From Bayley, N., and Tuddenham, R. D. Adolescent changes in body build. In 43d Yearb. Nat. Soc. Stud. Educ., Part I, 1944. Pp. 46–47. Quoted by permission of the Society.*)

Current Trends. The current trend is away from isolated measures of height and weight. A tall person may be slender, average, or broad in build; a short individual may be slight, in proportion to height, or stocky or obese. To obtain an estimate of the individual's body build, we might calculate such ratios as chest circumference/height, shoulder width/height, or any number of such combinations of transverse dimensions in relation to height. Various measurements are used. Only a few examples will be discussed (see McCloy, 1936, for other measurements).

Figure 37 presents the growth records of two boys. Chronological age, height, and weight are recorded just as they have been for many years. Next, an attempt is made to appraise body proportions by measuring

stem, or trunk, length, bi-iliac width, and biacromial width. Various ratios based on these proportions are used as convenient indexes for comparing with others. Case F-9 is an early-maturing boy whose body is broad at all ages and whose trunk contributes largely to his height. This boy's growth spurt occurs between the ages of 11.3 and 13.7. During this interval he gains 7.4 in. in height and 29.8 lb. in weight. Case E-12, on the other hand, is a late maturer who reaches the growth spurt around the age of 14. During the age interval 13.6 to 15.6, height increases 6.3 in. and weight 27.8 lb. Probably most of this increase occurs during the late fifteenth and sixteenth years, since both height and weight continue to show substantial increments at the age of 17. Case E-12 is slight in build, with longer legs and shorter trunk than case F-9.

These records are not complete, however. Bi-iliac and biacromial diameters coupled with weight cannot tell whether width is due to fat or to muscle. We therefore need more measurements. Let us suppose, for example, that we next measure the circumference of an upper arm, which includes both fat and muscle, and follow this with a measure of the thickness of a double skin fold, which excludes muscle. This would give a better estimate of the fat-muscle ratio. Other measures might be used. To form a fairly complete picture of the child's physique, we might select a series such as this:

1. Chronological age
2. Skeletal X ray
3. Height
    a. Standing height
    b. Porion height (ear to floor)
    c. Sternal-notch height (tip of sternum to floor)
    d. Sitting height
4. Width
    a. Biacromial diameter (shoulder width)
    b. Chest width
    c. Chest depth
    d. Bi-iliac diameter (hip width)
5. Weight
6. Thickness of skin fold
7. Vital capacity

From these measures we could readily calculate proportions of various body parts and work out a fairly accurate picture of physique and of the efficiency of the component parts. Today we are not satisfied with a silhouette of the child; we want to know just how well the skeleton and muscles serve the body, regardless of its size. We want to know, for example, whether chest circumference contributes to vital capacity by pro-

viding more room for the respiratory organs or whether it involves only fatty tissue which contributes little beyond the narrow limits desirable for insulation. Is the child equipped with a good set of muscles, or is his weight made up chiefly of fat?

The Wetzel Grid. Figure 37 illustrates a score card on which various physical measurements are clearly summarized. The Wetzel Grid is another example of a score card, called a grid, designed by a doctor named Wetzel (1948). Since it records the individual's progress graphically, it is simpler to interpret than columns of figures. For that and other reasons, it will be considered as an example of the more recent developments in anthropometrics.

Figure 38 illustrates the front page of the grid. Along the left margin of the graph is a vertical scale labeled "weight," and along the bottom a horizontal scale marked "height." When a child has been measured and weighed, his height and weight are plotted geometrically and represented by a point on the graph. Successive measurements give several points, which are joined to form a growth curve. These points will fall along the oblique ladder which runs diagonally across the grid. The ladder is divided into seven physique channels—a middle channel, M, with A_1, A_2, and A_3 to the left and B_1, B_2, and B_3 to the right (see upper end of ladder for labels). The central channels A_1, M, and B_1 are considered representative of average body build; the right-hand channels B_2 and B_3 represent slender build; and the left-hand channels A_2 and A_3 are for obese or stocky children. Thus, a slim, small-boned child's progress will be plotted along channels B_2 or B_3; a broad, muscular, or obese child's growth curve will fall along A_2 or A_3.

Progress is considered normal as long as the child continues to advance along his own channel. This differs from the earlier norms, in that the child does not compete in growth rate with children of other physiques but merely with his own previous record. It can be seen at a glance whether his development is constant or whether the curve moves across to another channel. It he deviates to the left, he is gaining faster than usual and is said to incur a *growth lead*. If he deviates to the right, his progress is retarded, thus incurring a *growth lag*.

Auxodromes. The numbered transverse lines cutting across the channels are called *auxodromes*. Their numbers are convenient weightings, or codes, for designating developmental levels, as shown in the fifth column of the script (upper left hand corner of Fig. 38).

Auxodromes serve another purpose, however. It will be noticed that they run across to the right-hand margin of the grid, where the same numbers designate developmental levels along the left margin of the larger squares. Let us call this section B of the grid. Now, if the child's developmental level (as traced across from section A) is plotted against his
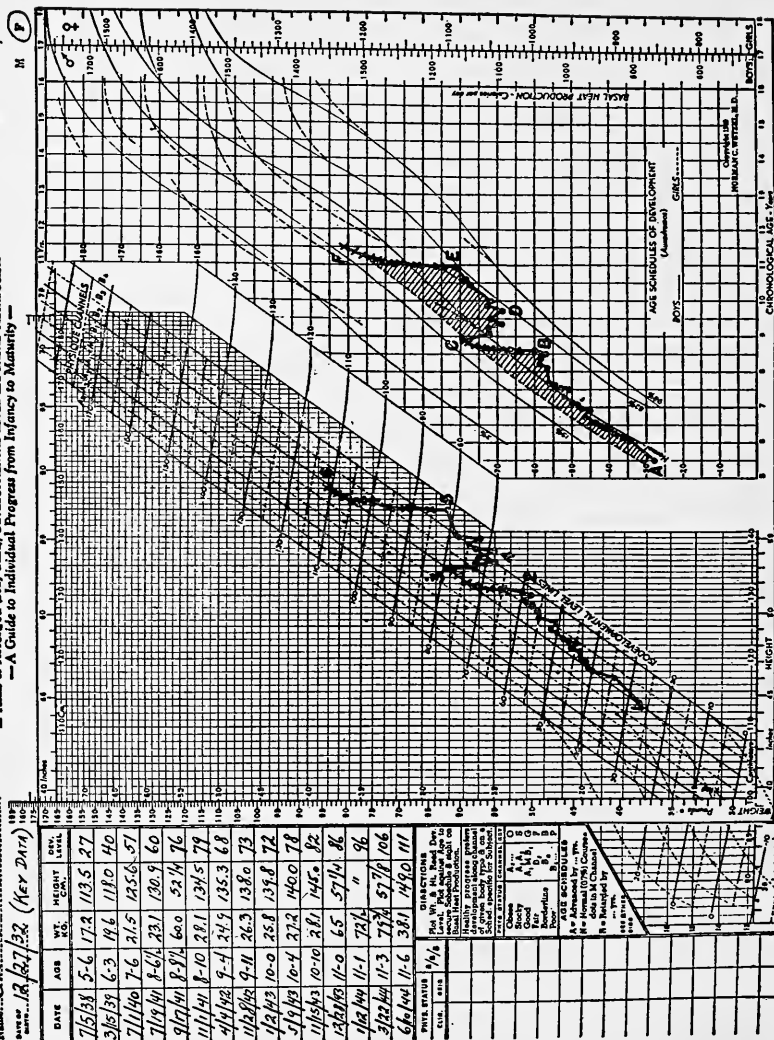
Fig. 38. A diagram of the Wetzel Grid. (From Wetzel, N. C. The role of the grid technique in a physical fitness program. Medical Woman's Journal, November, 1948, P. 5. By permission of the author.)

chronological age (noted along the horizontal axis of section B), you will have a second series of plotted points, which are likewise joined to form a curve. In section A, normal progress consists of following one channel; in section B, it consists of following or paralleling one of the curving lines which represent the normal metabolic rate (BMR) for children of dimensions similar to the subject under study. BMR expressed in calories is noted along the extreme right margin. This section of the grid accordingly shows whether or not the child is normal in heat and energy production. Deviation to the right again indicates a subnormal level; deviation to the left, above-normal level.

The girl whose growth is plotted on the particular grid illustrated in Fig. 38 was first measured at the age of $5\frac{1}{2}$ years. She was of slender build at that time, and the initial plotted point fell on the border between channels B_1 and B_2. Her progress was fair for 2 years. Between the ages of 7 and 8 years, however, development began to fluctuate, and she gradually moved across channel B_2 and into B_3, incurring a growth lag. In section B, fuel debt is indicated at this time, that is, fuel or calorie intake was inadequate to meet body needs. She corrected this, and by the ninth year was back in her normal growth channel with BMR also normal. During the next year she relapsed, and for 2 years showed poor progress in height and weight gains and again incurred considerable fuel debt. At the age of 11, this began to correct itself, and she returned to her normal B_2 channel and to normal metabolic level.

From this child's record, we can immediately note sex, chronological and developmental age, height, weight, body build, consistency of progress, direction and extent of any abnormal deviations, rate of development, BMR, and fuel debt or surplus, if any exists. Thus it forms an excellent record of physical development throughout the school years. Not all difficulties have been accounted for, however. The channels do not tell whether the child is broadly built or obese, for example. To check this, other measurements are needed. Growth lag or growth lead shows direction and extent of deviations but gives no clue to cause and hence to treatment. Research is in progress in these areas.

Correlation of Physical and Emotional Development. Considerable detail has been presented concerning the Wetzel Grid, not so much for the sake of the grid itself as because of possible correlations between physical and emotional development which have come to light as a result of using the grid as a recording device. Long ago, Kretschmer suggested that physique, or *somatotype*, as he called it, was related to personality. Various more recent attempts have been made by Sheldon *et al.* (1942) and others to explore this tentative relationship further. So far, at least, these attempts have not proved very fruitful. Apart from these attempts, ample evidence has been accumulated to show that extreme deviations from

normal physical development—precocious puberty, with consequent cessation of growth, or deformity of various skeletal parts—give rise to emotional problems and may permanently warp personality. The converse—that emotional stresses may retard physical development—has not been studied very carefully to date. It is this hypothesis that the proponents of the Wetzel Grid have postulated.

The various proponents of the Wetzel Grid maintain that growth lags such as those represented in Fig. 38 may be due to (1) physical or (2) emotional causes (Binning, 1948, 1950; Fried and Mayer, 1948). They observed that growth lag is fairly common prior to or following tonsillectomy, appendectomy, and other diseases but, on the other hand, frequently occurs where no physical disturbances are diagnosed. In searching out causes for such growth lags, these investigators probed into family histories and found that growth lag or lead (occasionally) resulted more frequently than chance where children were subjected to emotional stress—a parent died, a sister was sent to a sanatorium, a teacher was hostile, a father enlisted or was sent overseas, parents were divorced, or any of dozens of similar stressful situations. Moreover, the degree and duration of the growth lag corresponded closely with the degree and duration of the stress situation much too frequently to be coincidental. Apparently, then, stress situations can and do result in distorted physical-growth patterns.

SKELETON AND TEETH

Whether large or small, the human skeleton forms the framework to which the muscles are attached, protects the delicate inner organs, and provides leverage for motor activity. It consists of bone, supplemented at various points such as the tip of the nose by a transparent, plasticlike substance known as cartilage.

Development of Bone. Most bones, especially the long bones of the arms and legs, are first formed of cartilage of the same general shape as the final bones. These are called *cartilage models*. Early in the first postnatal year, various mineral salts (chiefly calcium) are deposited in the cartilage models, and bone is formed. This process is variously known as *calcification* or *ossification*, that is, bone formation. Mineral salts are first deposited in small spots called *ossification centers* in the long bone shafts (*diaphyses*) and gradually spread to each end of the bone. While this is in progress, new ossification centers appear at both ends of the bone shaft. These are known as *epiphyses*.

During the growing years, the diaphysis is separated from the epiphyses by cartilage discs called *growth plates*. These growth plates continue to enlarge and account for the increase in length of the bone. When the growth plates cease to develop, the diaphysis fuses with the epiphyses at both

ends, and bone growth stops. Increase in bone thickness is accomplished by the deposit of layer after layer of bony material on the outer surface of the shaft.

Normal ossification depends on a number of conditions such as (1) well-balanced diet; (2) adequate quantity of vitamin D, which is indispensable to the absorption of calcium and phosphorous and to their deposition in the bone; and (3) adequate secretion of such hormones as thyroxine, phyone, and sex hormones.

Let us now see how this relates to growth in height. As has already been noted, an individual's height depends on the length of the long bones of leg and thigh plus the length of the spinal column or its individual vertebrae. It was also pointed out (Chapter 4) that skeletal growth depends on the carefully timed reciprocal action of phyone and sex hormones, with the assumption, of course, that diet is adequate. Just prior to puberty, the concentration of phyone is high, and so the long bones grow very rapidly, accounting for the growth spurt in height which has already been discussed. Soon the sex hormones—produced by the stimulating action of gonadotropic hormones—begin to increase in amount and gradually reduce either the quantity or the effectiveness of phyone, eventually stopping its action completely (Greulich, 1944). The drop in phyone output (or effectiveness) results in a slowing down of bone growth. Finally, as phyone concentration or its effectiveness reaches a certain low level, the growth plates of the bones disappear, and the diaphyses fuse with their epiphyses. When such fusion has occurred, bone growth is no longer possible. Fusion in bones of the hand occurs around the age of 17 for girls and 19 for boys. Some bones continue to grow longer than others; fusion in hipbones, for example, occurs several years after it is completed in the hand.

Number of Bones. Probably most high-school texts say that "the human skeleton consists of 206 bones," perhaps listing the names of the more important ones. This information is based on examination of the adult skeleton, for, strangely enough, the number of bones in the body also varies with age. At birth, we have 270; at puberty, 350; and in adulthood, 206. Between birth and puberty, new bones appear in definite order. These are formed as new ossification centers emerge at different times in different parts of the body.

The appearance of new bones can be seen clearly in an X-ray plate. For this reason and also because the density of calcification may be observed, X rays have become the most accurate, though expensive, way of appraising developmental age. A child of 2 years, for example, has a great deal of cartilage and only two or three wristbones; when he begins school at 6 years, more of the cartilage models have become calcified and up to seven wristbones may be present. The eighth and final wristbone (a *sesa-*

moid bone) appears around the age of 11 to 14 years and is an excellent indicator of approaching puberty. Since the sesamoid wristbone appears about 2 years before puberty, it may be seen earlier in girls (11 to 12 years) than in boys (13 to 14 years). After puberty, no more bones are formed, but some of the 350 begin to fuse—also in regular order—reducing the total to 206 by adulthood.

Age Changes in Bone Composition. As bones grow in size and increase in number, they also change in chemical composition. In contrast to the adult's, an infant's bones contain more water and proteinlike substances and less mineral, so that they tend to be soft and spongy. Such plasticity has a definite advantage, for the young child is exposed to innumerable falls and blows as he learns to walk, climb, and balance. He is less prone to breakage than his grandfather, and his bones knit more quickly. On the other hand, a child's bones are more easily bent; carrying heavy loads, wearing too tight clothing, or stooping continuously over an ill-fitting school desk may easily warp them out of shape permanently. Posture is especially important during the early growing years, for, as bones calcify, posture becomes increasingly difficult to correct.

As bones enlarge, their cartilage characteristics gradually disappear, and they become denser, harder, and more brittle. During the process of ossification, there is a gain of roughly 60 per cent in mineral content.

From the discussion so far, it might appear that maximum bone development is achieved in late adolescence. This is not true. Ingalls (1931) weighed the entire skeleton as well as the individual bones of 100 males aged 19 to 78 years. He found that the peak of bone weight occurred around the age of 35 when, as he said, the skeleton "is in its prime, full blown." Following this peak, decline set in. Ingalls considered this the first indication of old age. Bones become lighter, more porous, and subject to surface markings. Decline was gradual up to the age of 65, when the curve sloped downward rapidly. Rate of decline varied for different bones but over the years was distributed as follows: bones of the lower extremities decreased in weight by 47 per cent; upper extremities, 19 per cent; axial skeleton, 19 per cent; and skull, 15 per cent.

Skeletal X rays. Because of the orderly appearance of new bones and equally orderly sequence of fusion and mineralization, skeletal X rays have become the most accurate index of maturation and subsequent aging. Perhaps the outstanding pioneers in this field of research were Krogman (1941) in the animal field and Todd (1937) on human beings.

Long before most research men envisioned any relationships between the X-ray plate and the nature-nurture problem, for example, Todd was using X rays in lieu of birth certificates, was pointing out familial resemblances and differences, and was predicting chronological age from skeletal age. His early *Atlas of Skeletal Maturation* has been superseded for

practical purposes by Greulich and Pyle's *Radiographic Atlas of Skeletal Development of the Wrist and Hand* (1950), an examination of which will prove most helpful. The importance of such work is just beginning to be recognized.

Figure 39 shows three X rays of the left hands of children at 2, 6, and 16 years, respectively. The 2-year-old has two or three wristbones; the bones of the fingers are short and lightly calcified with great gaps between adjoining bones. The 6-year-old child has several more wristbones, longer and more densely calcified finger bones, and better articulation at the joints. In the postpuberty child, the set of wristbones is complete; the epiphyses have completely calcified and fused with their shafts, and all spaces at the joints have been filled. These may be compared with an additional X ray of a male, aged 78, also shown in Fig. 39. The most noticeable change in old age is a reduction in the density of calcification in all bones, with an increased density around the joints and heavy deposits in some bones, especially those of the wrist.

Teeth. The child has two sets of teeth; the temporary set of 20 "baby teeth" are eventually replaced by the permanent set of 32 teeth. Dental development begins during the mid-fetal period and continues until the last molars, the "wisdom teeth," make their appearance in the early 20's.

At birth, both temporary and permanent teeth are developing in the infant's jaws. Temporary teeth begin to emerge any time from the third to the sixteenth postnatal month, the average being at 6 months. Usually the first to erupt is a lower front tooth. By the age of 3 years, the temporary set is generally complete, although individual differences among children are great. Figure 40 records the average time of appearance of the various baby teeth.

Permanent Teeth. The quiescent period following the appearance of the temporary teeth is interrupted by the emergence of the first permanent tooth around the age of 6. A permanent tooth begins to calcify as soon as its predecessor has erupted. As it approaches functional level, the root of the temporary tooth is reabsorbed, so that by the time a child begins to shed the baby teeth only their crowns remain, and removal is accordingly painless. Permanent teeth continue to replace the original set throughout childhood. At the age of 6, most children have 1 or even 2 of the permanent set; at 8 years, 10 permanent teeth; at 10, between 14 and 16; and at 13 years, all except the wisdom teeth, which emerge between the seventeenth and twenty-fifth years. Figure 40 shows the approximate ages at which the various permanent teeth may be expected to appear. In line with their earlier physical maturation, girls' teeth erupt at earlier ages than boys'.

As with bones, vitamin D, calcium, and other such substances are essential to the growth of sound, well-formed teeth. Interestingly, both bones
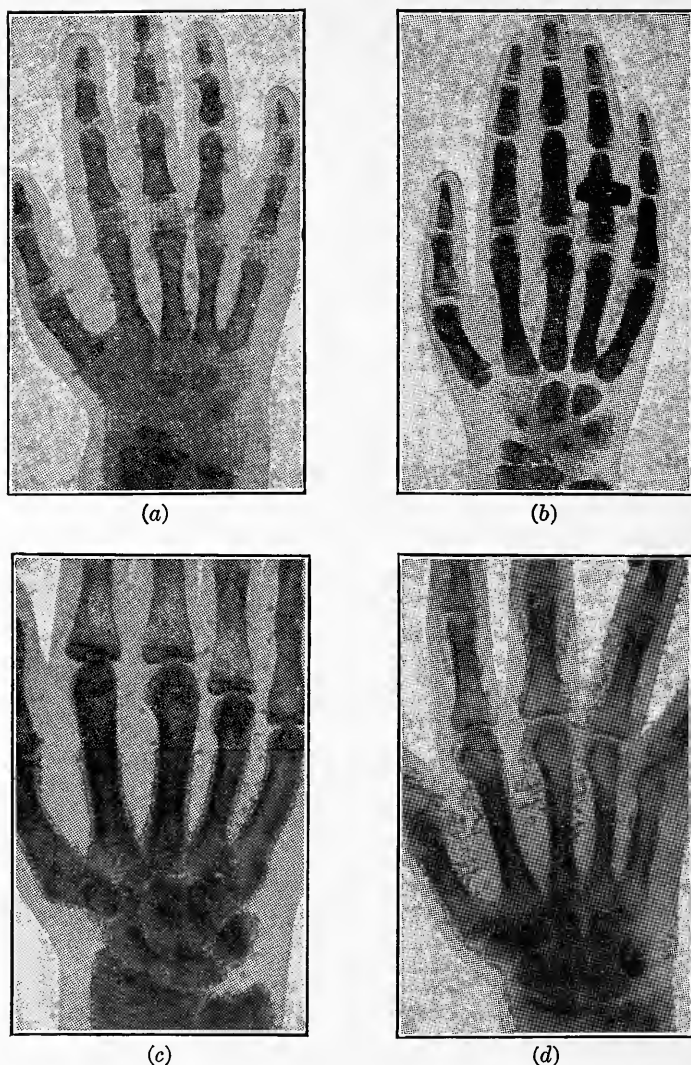
Fig. 39. X rays of the hands of four male subjects aged (a) 2, (b) 6, (c) 16, and (d) 78 years. (*From Flory, C. D. Osseous development in the hand as an index of skeletal development. Monogr. Soc. Res. Child Develpm., 1936, 1, No. 3. X ray of aged hand provided by courtesy of Dr. D. L. MacRae, Montreal Neurological Institute.*)

and teeth are accurate indicators of disturbances in either health or nutrition during the growing years. During the growth process, teeth develop layer after layer of enamel in the same way as trees grow annual rings. If the process is disrupted for any reason, these layers tend to be irregular or otherwise accentuated. The lines or ridges in a layer may generally be seen under a microscope, but, if the disturbance is sufficiently severe, the

resultant irregularities may be observed with the naked eye. Adult teeth thus reflect the health history of earlier years.

Teeth in Old Age. Loss of teeth with age is so common as to be characteristic of advancing age. This loss is due to disease rather than to the aging

Temporary teeth

Name	Age expected
Central incisor	8 to 12 months
Lateral incisor	8 – 12 "
Canine (eye tooth)	18 – 22 "
First molar	12 – 16 "
Second molar	24 – 32 "

Upper

Right   Left

Name	Age expected
Second molar	24 to 32 months
First molar	12 – 16 "
Canine	18 – 22 "
Lateral incisor	10 – 14 "
Central incisor	6 – 8 "

Lower

Permanant teeth

Name	Age expected
Central incisor	7 to 8 years
Lateral incisor	7 – 8 "
Cuspid or canine	12 – 14 "
First bicuspid	9 – 12 "
Second bicuspid	9 – 12 "
First molar	6 "
Second molar	12 – 15 "
Third molar (wisdom tooth)	17 – 25 "

Upper

Right   Left

Name	Age expected
Third molar (wisdom tooth)	17 to 25 years
Second molar	12 – 15 "
First molar	6 – "
Second bicuspid	9 – 12 "
First bicuspid	9 – 12 "
Cuspid or canine	12 – 14 "
Lateral incisor	7 – 8 "
Central incisor	7 – 8 "

Lower

FIG. 40. Average age of eruption of temporary and permanent teeth. (*From Anderson, J., and Goodenough, F. Your child year by year. Parents' Magazine, 1930. Used by permission.*)

process, however, and may result from faulty nutrition or invasion of the oral cavity by germs and destructive bacteria. Dental decay (*dental caries*) is common among children, accounting for 85 per cent of all extractions during the first decade, but decreases to 26 per cent by the sixth decade. This decrease of dental caries may be due to the higher calcium content of older teeth. *Peridontal disease* continues the destruction begun by dental caries. This is a diseased condition of the bone and membranes in which the teeth are embedded. It assumes responsibility for no extrac-

tions below the age of 10 but quickly increases to account for 61 per cent in the sixth decade. As a result of early caries and later peridontal disease, we are forced to report the tragic finding that by the age of 70 years, 80 per cent of all females and 70 per cent of all males have lost all of their teeth (see Robinson and Boling, 1952).

Loss of teeth modifies facial contours and alters speech, especially the consonants. More serious is its effect on the digestive process and, through it, on other body processes. Dentists claim that "with every tooth lost, you forfeit a year of life."

Use of Fluorine. Some hope of preventing the high incidence of dental decay is afforded by the use of fluorine. Recent research has demonstrated fairly conclusively that application of fluorine to childrens' teeth reduces incidence of decay (Easlick, 1948). Indications are that similar application to the teeth of young adults may be equally effective (Klinkenberg and Bibby, 1950). The precise physiological mechanism by which fluorine works to protect teeth has not yet been determined. It is possible, however, that general use of this chemical may reduce dental loss even in old age. Adding fluorine to drinking water in some communities at present seems to be a step in the right direction.

MUSCLES

The skeleton has no function independent of muscles. Without the connecting musculature, the bones would offer little protection, for they could not remain in place. Without muscles, erect posture would be impossible. Levers would be of little value without the muscle cables which raise and lower them. Moreover, muscle contractions are responsible for the movements of the various internal organs whose activities are essential to life. Thus, muscles are indispensable to respiratory movements, heart action, digestion, and elimination of wastes. Even speech owes its existence to the muscles of the face and throat.

Early Changes in Muscles. Between birth and maturity, muscles increase in weight about 40 times. At birth, 23.4 per cent of the total body weight consists of muscle; at the age of 8, about 27.2 per cent; at 15 years, 32.6 per cent; and a year later, 44.2 per cent, which is about the same as the proportion for adults. These values indicate that during infancy and childhood muscles grow more slowly in proportion to total body weight; after puberty, the rate of muscle growth increases. This increased muscular growth around puberty is reflected in children's great interest in physical activity, boasting about their strength, and selecting leaders on a basis of physical prowess.

Muscle Composition. In addition to the increase in muscle bulk, the

composition of muscles also changes. Roughly 72 per cent of a young child's muscles consist of water as compared with 28 per cent of solids. After puberty, the proportion of water decreases to 66 per cent, while the solid constituents rise to 34 per cent. The relatively high water content of the child's muscles makes for more delicate musculature, and since muscles are also poorly attached to the bones during early life, young children tire easily. Coupled with short attention span, this accounts for their play habits. They need to change from one activity to another so that different muscle groups may participate in the effort.

Because it requires considerable effort by opposing muscle groups to maintain constant posture for any length of time, children should be permitted freedom of movement and should not be expected to maintain either sitting or standing positions for long periods. Sitting upright at attention or sitting motionless on a chair for even several minutes is too much for a preschool child. Even army men, physically fit and at the peak of development, frequently collapse after standing motionless on a parade ground.

Muscular Changes in Later Years. Muscles continue to grow for many years. Todd (1942) observed that in both males and females the skeletal muscles increase in bulk and density until the age of 50. About a decade later, the first degenerative changes begin to appear, and both bulk and density decrease in both sexes and in both physically active and nonactive people. Such findings are interesting, especially as we shall see presently that strength reaches a maximum around the thirtieth year and begins to decline shortly thereafter, despite the further increases in bulk and density of muscles.

Although skeletal muscles undergo structural changes in later life, the smooth muscles appear to retain their normal characteristics into later senescence. Häggqvist (1931), for example, who studied the smooth musculature in human intestines in subjects ranging from 8 to 74 years, found no age changes in these tissues. Here is another illustration of the fact that body structures concerned in some way with vital functions undergo little if any degenerative change. As we know, smooth muscles occur in the walls of various internal organs such as blood vessels, stomach, intestines, urinary organs, and respiratory organs—organs which are essential to vegetative functions and to the maintenance of life itself.

Muscular Strength

Muscular strength, an important aspect of physical development, largely determines how the individual will adjust to many situations. The child who is physically weak, for example, experiences greater difficulty in adjusting to the robust activities of his playmates than the one who is

physically strong. In later years, muscular strength is a factor in determining whether the individual is capable of holding a job and what kind of job, as well as in guiding selection of leisure-time activities.

Measurement. Muscular strength may be appraised by use of instruments known as *dynamometers*, which gauge strength of hands, shoulders, back, legs, and other body parts. In measuring strength of grip, for instance, the subject squeezes a hand dynamometer as hard as possible. A
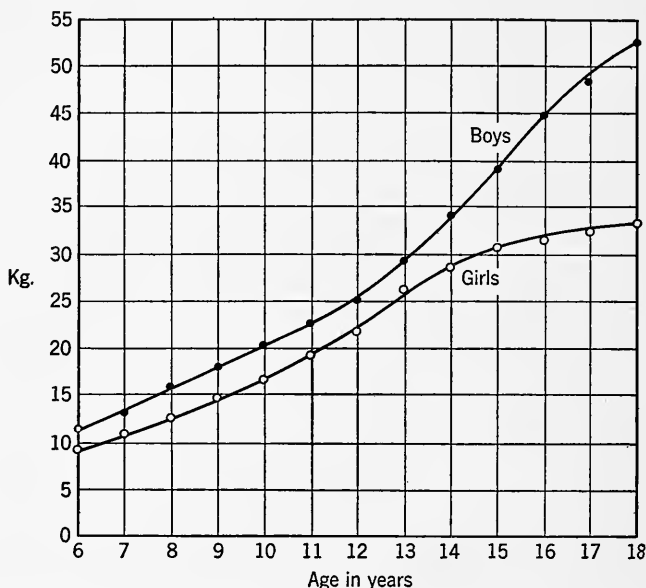
FIG. 41. Growth curves of strength of grip. Note the divergence at puberty. (*After Meredith and Metheny. From Jones, H. E.   The development of physical abilities. In 43d Yearb. Nat. Soc. Stud. Educ., Part I, 1944. P. 103. Quoted by permission of the Society.*)

pointer indicates the number of pounds or kilograms on a convenient scale. Slightly different dynamometers are used for other muscle groups.

Muscular Strength in Early Years. Muscular strength, as evidenced by strength of grip, shoulder thrust, shoulder pull, and various other measures, increases steadily throughout childhood and adolescence (Meredith, 1935; Metheny, 1941). Between the ages of 3 and 10 years, strength of grip, for example, doubles for both boys and girls. Boys maintain superiority over girls at all ages, through puberty and adulthood.

Figure 41 illustrates clearly that although boys are superior to girls in strength of grip even during the early years, the growth curves do not diverge greatly until puberty, when boys surpass girls by 40 per cent. Grip strength continues to increase beyond the age limits of this particular graph, rising well into the late 20's, when males double the values of

females. Shoulder strength (as appraised by tests of both shoulder thrust and shoulder pull) increases at a rate similar to strength of grip. The pronounced sex difference after puberty is related to the greater muscular development of most boys. Furthermore, bigger hands and broader shoulders provide boys with better leverage.

Changes in Muscle Strength throughout the Life Span. A summary of studies of strength of subjects aged 10 to 70 or 80 years is provided in Fig. 42. Perhaps the most amazing feature of this diagram is the strikingly uniform picture of age changes—especially as these data were gathered over a period of 100 years by investigators in different countries, employing widely different apparatus. An examination of the figure shows that, in general, muscular strength follows a systematic trend, increasing up to the late 20's and subsequently declining—usually at an increasing rate.

This picture covers changes of muscle groups studied as a whole. Let us now look at the age changes in strength of individual muscle groups. Perhaps the most comprehensive study of such changes was carried out by the Russian investigator Ufland (1933), who studied flexors and extensors of the forearm, the hand muscles, and the muscles of the back. They all showed a characteristic increase in strength from the time of puberty (and earlier, as evidenced by other studies), reaching a maximum between the ages of 25 and 29 years. The amount of increase, however, varies for different muscle groups. Taking 18 years as a base line, Ufland observed that in handgrip and flexion of the forearm, the maximum strength attained at 25 to 29 years is 20 per cent above that of 18 years; flexion of the thumb increases 10 per cent; extension of the wrist, 6 per cent; and flexion of the wrist, 4 per cent; while the extensors of the back increase only 2 per cent in strength.

Just as each of these muscle groups has its own peculiar course of strength increase, so it has its own peculiar course of decline. The muscles showing the greatest age decrement are those of the back and the biceps of the upper arm, each of which decrease 55 per cent between the age of peak performance and 65 years. The muscles evidencing the least strength decrement, roughly 20 per cent by age 65, are the wrist flexors and extensors and those involved in handgrip. Evidently back muscles may fail to support the earlier erect posture with their usual ease, but the politician's handshake remains as firm as ever! These findings on differential decline are supported by data of other investigators (Quetelet, 1835; Galton, 1884; Fisher and Birren, 1947). Differential decline applies to both males and females (Schochrin, 1935).

The above findings concerning differential decline of muscular strength are of practical significance. They suggest that in any task involving primarily hand strength only, a small decrement may be expected as years advance. Jobs involving prolonged standing, bending, or unsupported

sitting, in which back muscles play a major role, will handicap the older worker who will suffer accordingly.

Strength in Extreme Old Age. For the most part, the above-mentioned studies have been concerned with an age range up to 70 years. Data on
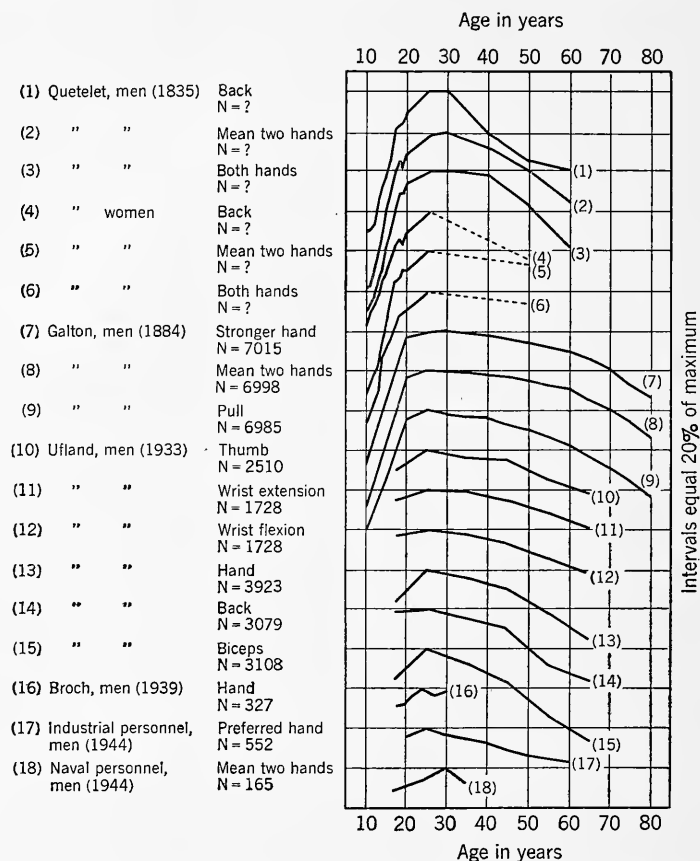
Fig. 42. Relationship of strength to age as determined by various investigators during the past 100 years. Values are plotted as per cent of the maximum. Each curve is drawn to a different base line, separated by 20 per cent from the next. (*From Fisher, M. B., and Birren, J. E. Age and strength. J. appl. Psychol.*, 1947, **31,** 493. *By permission of the American Psychological Association.*)

very old individuals are totally lacking except for one study on a group of 355 Japanese aged 70 to 100. One of the surprising findings of this study was that although strength of grip was low, there was scarcely any decline between ages 70 and 100—as a matter of fact, some of the 90-year-olds showed almost the highest scores (Kubo, 1938). Whether a similar leveling off of strength beyond the age of 70 exists for other muscle groups than those of the hand remains to be seen.

Mechanisms Underlying Changes in Muscle Strength. It is generally agreed that the increase in muscle strength during childhood is due primarily to maturation of the neuromuscular system, with environmental influences exerting only a minimal effect. Strength decrement after the age of 30 has presented more of a problem. One common explanation is that with advancing years people become more and more occupied with sedentary jobs and that loss of strength results from disuse of muscles. Although this factor may operate in some of the studies, it cannot account for the decrements recorded in Ufland's extensive survey or for Fisher and Birren's findings (see graphs 10 to 15 and 17 of Fig. 42). All subjects in these two studies were engaged in occupations requiring considerable physical activity, so that occupational exercise was considered constant. It is doubtful that avocational exercise contributed much to the variations among these workers. Another factor, usually suggested in studies comparing various age groups, is motivation. Unfortunately, we have no data on the importance of motivating factors in strength tests in older subjects.

Neural Mechanisms. It is doubtful that strength decrements are caused by changes in muscle structure. As has been noted, degenerative changes in muscles commence much later (age 60) than strength decline. A more fruitful approach may be to look at age changes in the neural mechanisms which control muscular movements and coordination. In Chapter 3 it was pointed out that disintegration and disappearance of the Purkinje cells of the cerebellum begin between the ages of 30 and 40 years. It was also stated that the pyramidal tract of the elderly possesses only two-thirds as many fibers as it did in youth. These data suggest that at least some of the loss of muscular strength is due to changes in the cerebellar and pyramidal systems. Undoubtedly other factors such as practice and motivation and skeletal, glandular, and metabolic changes are also involved.

Sex Hormones and Restoration of Muscular Strength. Since the reduction of sex hormones from middle age onward was definitely established, various investigators (*e.g.,* Simonson, 1947) have puzzled over the possible relationship between such reduction and decrease in muscular strength and endurance. If sex hormones were partly responsible, then we might expect that artificial administration would improve muscular performance. The few experimental data available support this view.

In 1944, Simonson *et al.* administered testosterone to six males, aged 51 to 68, who complained of excessive fatigue but were otherwise healthy. The test treatments were controlled by giving placebos (control treatments) at certain intervals. Various measures of strength were made both before and after testosterone as well as placebo treatments. Results showed a significant increase in back-muscle strength in all six subjects after testosterone therapy. Some slight improvements were also noted for

other muscle groups, but the changes were not statistically significant. The marked effect on back muscles as compared with others is interesting, for it is the back muscles which show the greatest age decrement (55 per cent as compared with 20 per cent, see Fig. 42).

Such evidence suggests that at least some of the strength decrement is related to the drop in sex-hormone level. Further support is offered by Samuels *et al.* (1942), who failed to obtain any increase in muscular strength after testosterone treatment of normal young men whose sex-hormone level was at a maximum, and by Simonson *et al.* (1941), who noted an increase in strength after similar treatment of castrates and eunuchs whose sex-hormone level was low. In the latter study, strength increase was again especially noticeable in back muscles.

While these findings are interesting, caution is essential, for the conclusions to date are based on a handful of cases, many of whom were preselected on a basis of proneness to fatigue. Although such artificial methods may actually increase efficiency of some parts of the organism, they may have deleterious effects on other body structures and functions. Hoskins and Small (1940), for example, found that administration of sex hormones increased the activity of rats but produced a serious loss of weight. Considerably more research is needed before we can accept the above findings. Nevertheless, present results are both exciting and challenging.

MOTOR DEVELOPMENT

This chapter will describe some of the general characteristics of motor development, giving special consideration to locomotor skills such as walking, climbing, or running and to manipulatory abilities that enable us to handle objects with dexterity.

Motor skills are important at all ages, for they circumscribe the scope of environmental influences. Once the young child can walk, he is no longer confined to one spot. Moving about his own home and the ever-expanding outdoors, he not only gains a better knowledge of his natural habitat but also shares in play activities that teach him to get along with others, give him some appreciation of various values, and generally promote adjustment to society. During adulthood, motor skills are essential to holding a job as well as to leisure activities. With the coming of old age, declining motor abilities gradually force the senescent to retire from work and to limit recreation so that eventually his social participation is once again restricted to the home. Thus, in early life, increasing motor skills broaden the horizons; in later years, activities are narrowed by their decline.

MOTOR BEHAVIOR AND PHYLOGENESIS

For purposes of discussion, motor behavior will be subdivided into two parts: locomotion and manipulation. Different organisms show different degrees of skill in both locomotion and manipulation, and, as we shall see, man is not always at the top of the phylogenetic ladder.

Locomotor Behavior. As we scan the phylogenetic series from amoeba to man, we see great differences in the manner as well as the speed of locomotion. The single-celled amoeba has no specialized structures. If it is stimulated at any point, fingerlike protuberances bulge out from the body wall, and the organism moves off in the direction of these so-called *pseudopodia*. The name pseudopodia itself is enlightening, for it indicates that these temporary "limbs" are not true limbs but only makeshift, or pseudo, feet.

Although the amoeba lacks specialized structures, other protozoa such as the euglena and the paramecium show incipient specialization. In the

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euglena, a whiplike structure, the *flagellum*, at one end of the body serves to propel it forward. The surface of the paramecium, a slipperlike organism, has a number of hairlike processes called *cilia*, and the coordinated, beating motion of these cilia provides mobility. Even these early precursors of limbs are important, for they free the rest of the body for other tasks. From the protozoa upward, various structures take over the function of locomotion. For our purposes, however, little would be gained by examining the changes in detail. We shall note only a few landmarks.

Vertebrates. In the vertebrates, in which we are primarily interested, such organs as fins, wings, arms, and legs become means of locomotion. Although all these structures will move the animal from place to place, they are by no means equally efficient. The highly developed wings of birds, for example, enable their owners to maneuver so well and to travel so quickly that no other creature, including man, can remotely approach them.

Perhaps the most important phylogenetic change associated with locomotion is the assumption of an upright posture. This is peculiar to man. Some of the other primates assume an erect stance for limited periods, but they do not characteristically use such posture in locomotion. The change from walking on all fours to using only the hind limbs has some very important consequences—consequences which have reduced locomotor dexterity but otherwise improved ability to adjust to the environment. Release of the forelimbs enabled man to become specialized in manipulative activities such as making tools or weapons and to perpetuate learning through the art of writing. Moreover, as soon as the forelimbs became specialized for manipulation, the mouth and jaws, which formerly performed this task, gradually evolved along with other structures in their vicinity to serve as communicative mechanisms in speech. In addition to these direct and indirect consequences, an upright posture enlarged man's perceptual field, enabling him to cope better with his environment.

Manipulative Behavior. It is impossible to state with any degree of certainty at what point in the phyletic scale manipulative behavior first appears. We do know that it comes later than locomotion in the evolutionary sequence.

The structures concerned with manipulation are the mouth and the appendages. Many invertebrates such as insects manipulate objects by using both mouth and limbs. All vertebrates are capable of manipulation, making use of mouth, forelimbs or hind limbs, or a combination. Fishes, amphibians, and reptiles have little skill in this respect, since manipulation is restricted to the mouth. Birds, which use both beak and limbs, have greater ability, but it is only when we reach the mammals that we find any great advances.

Even the lower mammals such as rats can depress levers, pull in strings with attached objects, and pick up items from the floor with their forepaws. Although the rat is fairly skillful, the differences between rats and

primates are enormous. The monkey uses its "improved" forepaws—actually hands—to grasp and move a variety of objects. It can unfasten latches and use sticks and other tools. Thumb-finger opposition, which appears for the first time in the chimpanzee, permits even more intricate skills, since it makes for greater precision in handling small objects. The chimpanzee can pick up items as small as fleas with great adroitness; it can use spoons, forks, knives, and other eating utensils almost as well as human beings; and it even has an advantage over man in being able to grasp objects firmly with mouth and feet as well as hands.

In man, however, we reach the pinnacle of manual dexterity. One of the changes consequent to upright posture is the evolution of a larger thumb with increased flexibility; another is the greater control over individual digits. Especially significant to motor behavior is the tremendous development of the motor and sensory cortex of the brain which accompanies the evolution of the locomotor and manipulative structures already mentioned.

EARLY MOTOR DEVELOPMENT: PRESCHOOL PERIOD

The human neonate exhibits three types of motor responses. First are the random, generalized activities that involve the whole organism. Second, and in contrast to these "mass responses," there appear specific reactions evoked by a variety of internal and external stimuli—among them the tactually elicited grasp and Babinski and sucking reflexes. Most of these can be elicited long before birth (see Chapter 3). Third, there are complex behavior patterns that involve the coordination of several reflexes. An example of this type is the startle response, which may be evoked by loud noise or sudden loss of support and which is characterized by throwing the arms wide with fingers distended, throwing back the head, and extending the legs. As was mentioned earlier, considerable controversy has revolved around the question of whether these reflexes differentiate from a generalized state of activity or whether they are primary responses which are later integrated to form more complex behavior patterns. This question cannot be answered at present. However, some investigators believe that certain responses originate in one way and others in the other way (Munn, 1938).

Some Developmental Trends. Much of the evidence on postnatal motor development shows a trend from generalized to specific activity. The child who is just beginning to walk, for example, spreads his feet too far apart, lifts them too high, and randomly throws his arms out to maintain balance; later these exaggerated movements disappear. Again, the child who is just learning to pick up an object often uses hands, legs, and the whole body; later this generalized movement is replaced by thumb-finger opposition. Mass activity appears clearly in the performance of children

who are learning to print. The coordinated hand and finger movements are accompanied by facial contortions as well as general activity of legs and trunk, better known as squirming. These are not superfluous movements during early learning; they are all a part of the initial attempts to reproduce figures. Gradually they disappear, and in later childhood non-arm activities play only a minimal role in writing or printing.

Cephalo-caudal and Proximo-distal Trends. Both of these principles govern early motor development. In line with the cephalo-caudal principle, development of the head-trunk region precedes that of the lower limbs. The infant can lift his head within a few weeks after birth, but he is not able to stand alone until well toward the end of his first year. The proximo-distal principle applies equally well. Movements of the large muscle groups precede coordinated movements of fingers, for example.

Normative Data on Motor Development. Considerable information is available regarding the time of appearance of various motor activities. Several investigators have assembled such material in the form of age norms, which serve as rough guides for parents, pediatricians, and others concerned with the welfare of young children. One of the best-known norms is Gesell's Developmental Schedule (1928), which includes items such as the following:

One-month level
1. Lifts head from time to time when held to the shoulder
2. Makes crawling movements when laid prone on flat surface
3. Lifts head intermittently, though unsteadily, when in prone position
4. Turns head laterally when in prone position

Six-month level
1. Sits momentarily without support, if placed in favorable leaning position
2. Grasps with simultaneous flexion of fingers
3. Retains transient hold of two cubes, one in either hand

Twelve-month level
1. Walks with help
2. Lowers self from standing to sitting position
3. Holds crayon adaptively to make a stroke

Eighteen-month level
1. Climbs stairs or chair
2. Throws ball into box
3. Scribbles spontaneously and vigorously

Thirty-month level
1. Goes up and down stairs alone
2. Piles seven or eight blocks with coordination
3. Tries to stand on one foot
4. Copies vertical or horizontal line

[Based on material on pp. 128–135.]

Development of Locomotor Behavior

So far, we have been concerned with certain general trends in motor behavior. Let us now examine in more detail the development of various locomotor skills. Undoubtedly, one of the more dramatic achievements of the young child is learning to walk. This accomplishment is accordingly regarded as an important index of early development.

Stages in Development of Walking. As a result of much careful study, a great deal of specific information on the normal course of locomotor development is available. The mean age at which children begin to walk alone is 15 months. Independent walking is preceded by a long sequence of prewalking behavior, however. This sequence is illustrated in Fig. 43.

The newborn infant, lying in a prone position, can move his head but is unable to hold it up. By the age of 1 month he can raise it to a 30-degree angle and by 2 months he is able to elevate it higher, to hold it for a longer interval, and to raise his chest as well as his head. Although early signs of sitting with support appear at 4 months, it is not until the age of 7 months that he can sit alone for a few minutes. During the first half year, the mother can always be certain of her child's whereabouts. The youngster kicks, squirms, and rolls over but cannot yet raise himself or climb out of his crib. From this time on, however, she cannot be sure. Around the eighth month he can stand with help and, if placed on a supporting surface, can make some progress on his stomach in either a forward or a backward direction, using movements that are precursors of creeping and crawling. By 10 months, creeping is well under way, and the child can move about on all fours with body lifted well off the floor. A month later, he is able to walk when led; at 14 months, he can stand alone; finally, at around 15 months, he takes his first faltering steps on his own initiative.

At this point it is again important to note individual differences. Not all children go through all the stages shown in Fig. 43. Some may skip a stage or several stages; others may interpolate additional phases. One child may reach a stage earlier than the norm, another later. A few children walk independently at 10 months, others not until toward the end of the second year. Factors such as height, weight, body proportions, general health, and even sex may influence progress.

Maturation and Learning. At this point it is essential to consider the maturation-learning problem. Definitions have been controversial, but we shall assume that maturation of the neuromuscular system represents natural or hereditary influences and that practice or exercise represents nurture or environmental effects. The question, then, is this: does the young child "learn" to walk or does he walk without learning when physical structures have reached a certain developmental level?

Since the days when Carmichael observed that salamanders developed adequate swimming movements even in restricted environments where practice was negligible, many investigators have explored this nature-nurture problem. Dennis (1940a), for example, studied the locomotor progress of children of the Hopi and Navaho Indians. The Hopi infant is tied to a cradleboard for the first three months of life, except for the brief interval of an hour each day, and hence has little opportunity to practice locomotor movements. Nevertheless, Hopi children follow the same developmental pattern as American white children.
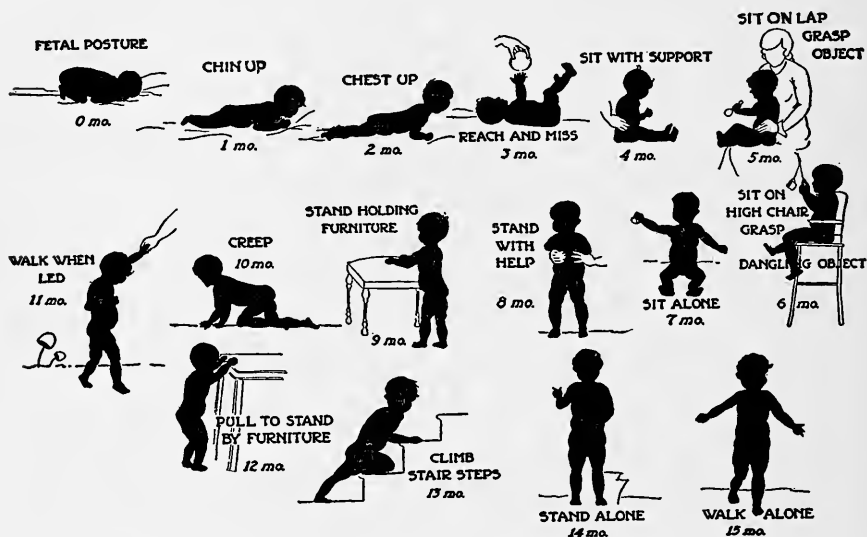
FIG. 43. Stages in the development of walking with approximate ages at which they appear. (*Mary M. Shirley's Motor Sequence Chart. From Faegre, Marion L., and Anderson, J. E. Child care and training. Minneapolis: University of Minnesota Press*, 1947. *By permission of the publishers.*)

Gesell and Thompson (1929) introduced the now famous co-twin method of study in this connection, observing the progress of identical twins T and C. When the twins were on the verge of climbing activities, twin T was given 10 min. of training every day for 6 weeks, while the control twin C received no training and was prevented from climbing stairs. At the end of the 6 weeks, twin C was given a brief 2-week training period. Performances of the twins were then compared. On the initial tests, twin T was more skillful, but twin C also managed to climb the stairs unaided. Two weeks later, twin C was just as proficient as her sister.

These and other experiments have led to the belief that both maturation and learning contribute to locomotor skill. Obviously, the year-old infant is not sufficiently mature to climb stairs with any amount of training. On the other hand, once the required maturation level has been

reached, little practice is needed to walk or climb, but practice results in smoother performance and greater confidence.

Development of Manipulative Behavior

The development of manual dexterity has long interested investigators. The child's reaching, grasping, and handling movements are so complex and rapid, however, that the full story of their development had to await the advent of the motion-picture technique. Movies enable us to record a situation accurately and permanently and then, through slow motion, to analyze the nature and sequence of various component movements.
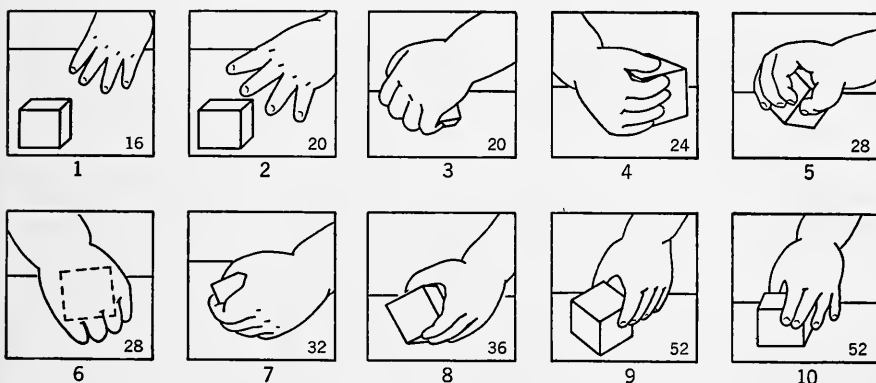
FIG. 44. Stages in the development of reaching and grasping with approximate ages (in weeks) at which they appear. (*Modified from Halverson, H. M. An experimental study of prehension in infants by means of systematic cinema records. Genet. Psychol. Monogr.*, 1931, **10**, 107–286.)

Stages in Reaching and Grasping. Working at the Yale clinic, Halverson (1931) recorded the reaching and grasping reactions of infants ranging in age from birth to over a year. Subjects were placed on a table, the top of which was marked off with lines to aid in study of direction and extent of movements. After attention had been attracted, a block was placed before the child, and his reactions were photographed. Halverson found that the development could be broken down into a number of fairly distinct stages. Figure 44 illustrates these steps, from the stage of purposeful reaching and grasping of the object with a primitive squeeze around the age of 20 weeks to the final achievement of thumb-finger opposition at 52 weeks. The stages are described as follows:

(1) At the earliest tested age, 16 weeks, the typical infant fails to make contact with the cube, though he is clearly regarding it; (2) contact will be made sometimes at 20 weeks; (3) and the grasping will be in the form of a primitive squeeze. (4) At 24 weeks the block is often corralled or swept in by a looping movement of the arm. (5) Later, (28 weeks) it is seized by a paw-like downward movement, the fingers curling about it with the thumb simply paralleling the fingers. (6) Then

the thumb comes to be placed on the opposite side from the fingers—the beginning of thumb-opposition that is so important in nearly all performances of the human hand. (7) A further advance (32 weeks) appears when only the radial (thumb side) of the palm is put in contact with the cube, and only the thumb and finger are used. (8) Later (36 weeks), only the tips of thumb and finger are used. (9) This is much more delicately done by a child several weeks older; and (10) eventually (52 weeks) he can reach for and seize the cube without resting the hand on the table [cited by Dashiell, 1937, pp. 90–91].

Handedness. During the first few months the infant is ambidextrous, making use of both hands. A preference for the right or left hand appears fairly early, however. Figure 45 shows the increase in right-handedness
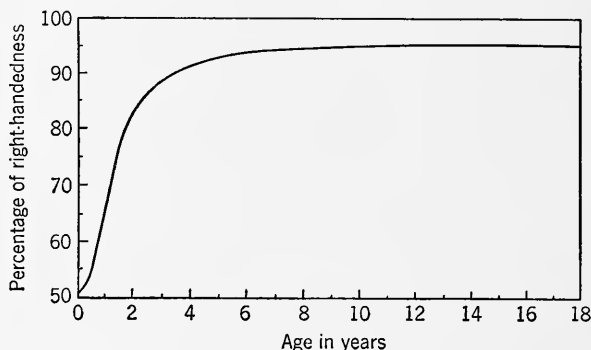
Fig. 45. Increase in right-handedness with age. (*From Hildreth, G.   The development and training of hand dominance: II. Developmental tendencies in handedness. J. genet. Psychol.*, 1949, **75**, 244. *By permission of the Journal Press.*)

from birth to 18 years. By the end of the first year, roughly 65 per cent are right-handed; by 2 years, 85 per cent; and by 6 years, when children begin school, the adult proportion of 95 per cent right-handedness has been reached.

The question of why right-hand preference develops is an old one, and numerous theories have been proposed to account for this phenomenon. In general, they may be divided into two groups: (1) theories which attribute hand preference to structural differences and (2) theories which attribute it to learning. Most popular of the "structural" theories of 15 or 20 years ago was the cerebral-dominance theory, postulating that the left cerebral hemisphere (governing the right side of the body) is functionally superior to the right hemisphere and thus determines handedness. This thesis has been severely criticized on various grounds. Hildreth (1949b), one of the more recent critics, who surveyed the experimental literature on handedness, concludes that "the neurological evidence in man and that gleaned from the lower animals suggesting the theory of cerebral dominance as *cause* of handedness rests on weak foundations." Another theory has proposed that the left hemisphere has a better blood supply. Still another

suggests that in some way the right arm is structurally superior to the left—perhaps because of the position of the fetus in utero. Neither of these hypotheses has much experimental evidence to support it.

Opposed to these structural theories is the second group of investiga-tors, who believe that social learning accounts for right-hand preference. This theory has also been criticized. In discussing the whole question of handedness, Munn (1938) states:

> Further research will be necessary before the basis or bases of handedness can be ascertained. There may be an unlearned "tendency" toward right-handedness; but hand preference develops gradually, it differs with the task in hand, and its susceptibility to training is quite marked. We also know that social pressure in favor of right-handedness is present quite early and continues throughout child-hood. Such facts strongly suggest a predominantly social basis of hand preference in human beings [p. 328].

Development of Some Complex Motor Skills

As soon as a child has learned to walk and to grasp objects, he is ready to integrate movements into more complex and refined patterns of motor activity. From the age of 2 years, he begins to exhibit more fluent move-ments in walking and such related skills as jumping, skipping, and climb-ing as well as rapid improvement in manipulative skills, expressed in such activities as dressing and undressing or throwing and catching a ball.

Locomotor Skills. The child's first faltering steps involve many excess movements not only of legs but also of the entire body. With increasing maturation and practice, these excess movements are eliminated, balance improves, the length of the step increases while its width decreases, toeing out is replaced by a forward-directed step, and both speed and direction improve rapidly. Increased coordination is clearly illustrated by the related activities of jumping, running, and climbing.

Gutteridge's Study. One of the most extensive studies of locomotor skills is reported by Gutteridge (1939), who observed about 2,000 children ranging in age from 2 to 7 years. Norms were compiled for several activi-ties as follows:

Jumping—is well developed in 42 per cent of three-year-olds and in 81 per cent at five years of age. Jumping from a higher to a lower level begins at two years of age, jumping over obstacles after four years. Long jumps are attempted from five years on.

Hopping—well developed in 33 per cent of four-year-olds with gradual incre-ments in skill; at 6½ years 90 per cent were skillful. Hopping on two feet precedes hopping on one foot.

Skipping—more difficult task than hopping for only 14 per cent of four-year-olds were able to skip. One year later, 72 per cent were able to skip and by six years, 91 per cent could.

Climbing—well established in about half of children by three years. By six years 92 per cent were proficient in this activity.

Tricycling—a motor skill well developed among 17 per cent of two-year-olds and 63 per cent of three-year-olds. By four years almost 100 per cent were successful. At this age "stunting" and various sorts of variations such as turning corners, riding backwards were frequently engaged in.

Manual Skills. Gutteridge (1939) also assembled data on the early development of such manual skills as ball throwing, catching, and bouncing, all of which demand well-coordinated movements of eyes, arms, and hands. Children under 3 years of age were unable to perform these activities. By 4 years, many of the children were practicing throwing, but only 20 per cent could throw well. At 5 years, 74 per cent were able to do so, and at 6, 84 per cent. Gutteridge describes their attempts: "The earliest method of throwing a ball includes mass movements of all the body. Gradually the movements become more specialized and the use of two hands gives place to the use of one hand in a 'clean throw.'" Here is an excellent illustration of the mass-to-specific trend in motor development which was discussed earlier. Ability to catch the ball and to bounce it shows a similar developmental sequence. Both of these tasks are more difficult than ball throwing; only 60 per cent of 6-year-olds can execute the necessary movements efficiently, as compared with 84 per cent for ball throwing.

Eating Skills. Another type of manual skill which has received careful investigation is hand control in eating. Perhaps the most careful work was done by Gesell (1940), who reports a definite developmental sequence:

Self-feeding (cup)

15 months: Holds cup with digital grasp. Apt to tip it too quickly with wrist rotation and thus spill most of the contents. Close supervision is necessary.
18 months: Lifts cup to mouth and drinks well. Hands empty cup to mother; if she is not there to take it, is apt to drop it.
21 months: Handles cup well: lifting, drinking and replacing.
24 months: Holds small glass in one hand and drinks.
36 months: Pours well from a pitcher.

Self-feeding (spoon)

15 months: Grasps spoon and inserts into dish. Poor filling of spoon. If brings spoon to mouth, is apt to turn it upside down before it enters mouth.
18 months: Fills spoon. Difficulty in inserting spoon in mouth; is apt to turn it in mouth. Considerable spilling.
24 months: Inserts spoon in mouth without turning. Moderate spilling.
36 months: Girls may have supinate grasp of spoon. Little spilling.

<div align="right">[From Gesell, 1940, p. 242. Used by permission.]</div>

Dressing Skills. Sometime during the third year, most children begin to take an interest in helping to undress themselves and, about a year later, are capable of dressing if clothing is simple. As might be expected, various items of clothing present different degrees of difficulty; stockings, for example, are easier to put on than shoes.

Some idea of the development in skill in buttoning and unbuttoning is furnished in one study in which children of different ages were dressed in specially constructed jackets with buttons on front, side, and back (Wagoner and Armstrong, 1928). It was found that buttoning was easier and hence occurred at earlier ages than unbuttoning. Although 2- or 3-year-old children could button and unbutton, it took them a long time to do either. Time required decreased with increasing age. Young children were able to perform these tasks only when buttons were located on the front or side of the garment, where they could see them. Ability to successfully manipulate buttons located out of sight in such places as the neck or back did not appear in most children until the age of 6.

Writing Skills. Writing skills also develop through several stages (Hildreth, 1936). At 2 years, the child is able to make a mark of some kind, but the marks are mere scribbles with a tendency toward vertical lines. Toward the end of the second year, horizontal lines and some systematic up-and-down movements begin to appear. Between the ages of $3\frac{1}{2}$ and 4 years, discrete symbols emerge, although they are not recognizable as letters. By the age of 5, certain simple letters such as H and O may be correctly formed, and a year later most letters may be reproduced. With school entrance, writing skills improve rapidly. It should be remembered, however, that all children do not reach the stage of "writing readiness" at the same age.

MOTOR DEVELOPMENT DURING LATER CHILDHOOD

So far, only the acquisition and initial stages of locomotor and manipulative skills have been discussed. Let us now examine the nature of development during elementary-school years. Investigations covering this age span are unfortunately limited.

Basic Motor Skills. As has just been seen, most of the basic motor skills are acquired during the preschool period. By the time they begin school, most children can run well and quickly, skip, hop, cycle, and climb. They can also throw balls and catch them reasonably well. The early school years, however, are marked by increasing smoothness and efficiency in execution of all such activities. Extraneous movements disappear, speed and coordination increase, and the various skills become automatic and are applied to new situations. With each passing year the child can

run farther and faster, jump farther and higher, and climb with less effort. Various tests have been devised to estimate progress in these respects.

Brace Test of Motor Ability. Some notion of age changes in motor abilities during the school years is afforded by a study of 800 boys and girls ranging in age from 9 to 18 years (Brace, 1927). These subjects were given the Brace Test of Motor Ability, comprised of 20 subtests, each measuring a complex skill such as kicking to shoulder height, making a full turn of the body while jumping, or balancing while maintaining a complex posture. Nine-year-olds are able to perform about 7 such tasks; at 13 years, 12 tasks; and at 18 years, 15 of the 20 tested skills. Thus, ability in such tasks appears to increase with age.

Speed of Movements. Studies of age changes in reaction time are numerous. Such studies usually consider reaction time as the interval elapsing between a light or sound stimulus and an overt response such as pushing a button or raising a foot. Philip (1934) found a steady age decrease in reaction time to both light and sound in children aged 9 to 16 years. Boys were 3 to 5 per cent faster than girls at all ages, but this apparent sex difference was attributed to the previous experience of the male subjects.

Ages	6	7	8	9	10	11	12	13	14	15	16
No. cases	33	58	66	42	18	38	45	43	28	24	207

FIG. 46. Speed of simple eye-hand coordination as a function of age. (*After Moore. From Munn, N. L. Psychological development. Boston: Houghton Mifflin, 1938. P. 329. By permission of the publishers.*)

Speed in eye-hand coordination also increases with age. In one extensive investigation of 602 children aged 6 to 16 years, the subjects were required to place marbles in holes, one at a time. An individual's score was the total time required to place 96 marbles. The results are shown in Fig. 46. The 6-year-olds needed 160 sec. to complete the task. Rapid improvement reduced the time to 95 sec. by the age of 16 years (Moore, 1937).

Studies of age changes in the speed of tapping have been especially popular. We shall mention only one by Pyle (1913), who tested 4,200 boys and 4,500 girls aged 6 to 18 years, recording the average number of taps made in a 30-sec. period. He observed an increase from 115 at age 6 to 160 at age 12 and 210 at age 18 (measurements were for right-hand tapping). Sex differences were negligible. Other studies of such motor skills

as buttoning, dressing, drawing, skipping, etc., all point to increased speed and efficiency during the growing years of childhood.

MOTOR DEVELOPMENT DURING ADOLESCENCE

Studies of motor development during adolescence are scarce. As was noted in the preceding section, motor activities involving reaction time, eye-hand coordination, and speed of tapping continue to improve well into the late teens.
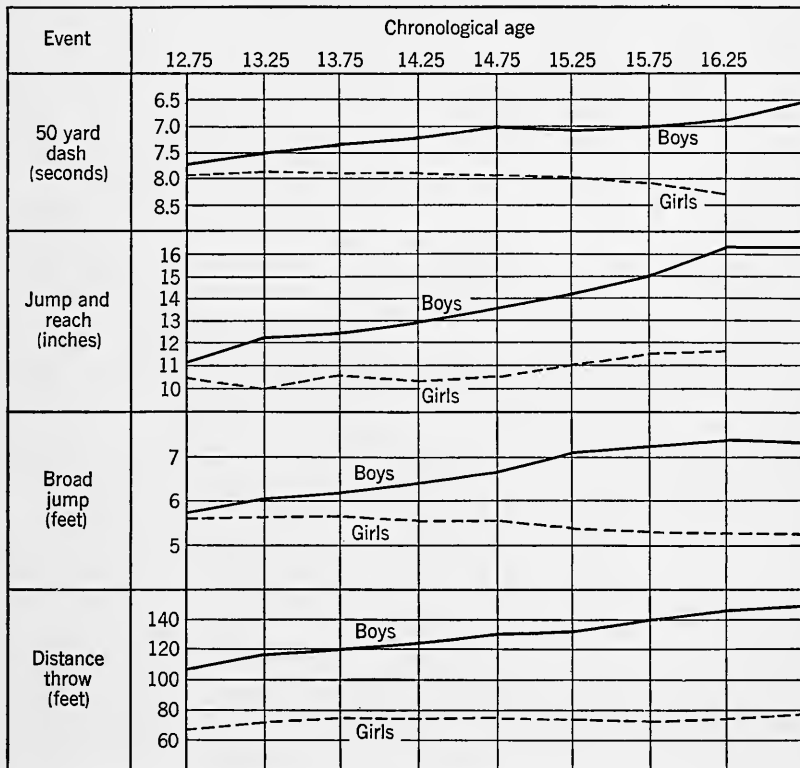
FIG. 47. Increase in athletic skills during adolescence. (*From Espenschade, A. Motor performance in adolescence. Monogr. Soc. Res. Child Develpm.*, 1940, **5**, *No.* 2, 49, 53.)

Athletic Performance. The only extensive work available on motor performance of adolescents concerns athletics. This study was carried out by Espenschade (1940), who tested 165 boys and girls aged 13 to 17, over a 4-year period. Running speed, distance of broad jump, height of standing high jump, and distance of ball throw were measured every year. The results are graphically recorded in Fig. 47. These curves show few sex differences at the age of 13 but diverge considerably as age advances. Boys

improve steadily in performance on all tests; girls, on the other hand, improve slightly in jumping and throwing, but their performance in the dash and the broad jump seems to reach a maximum at 13 years and declines thereafter. Sex differences thus increase with age. However, some of the inferiority in performance of girls may relate to declining interest and motivation rather than to decreasing motor abilities. Perhaps if such popular activities as tennis or badminton were used as tests the picture would be quite different.

Awkwardness. One of the major motor characteristics often attributed to adolescence is awkwardness. This popular notion is flatly contradicted by experimental literature, for motor coordination improves throughout the teens (Dimock, 1937; Espenschade, 1940; Kuhlen, 1952a). In one investigation of subjects aged 13 to 16.5, for example, a variety of tests was given, including such tasks as standing on one foot, walking a straight line heel to toe, and kneeling on both knees and then quickly rising. A poorly coordinated subject is either unable to perform these tasks or does them with great difficulty. When the results were plotted, they indicated progressive improvement in ability with no "dips" to mark regressions at any age level, including the time of puberty (Espenschade, 1940). Accordingly, it seems that adolescents have excellent coordination. In discussing this question, Kuhlen (1952a) states that although coordination is good, many adolescents *appear* to be awkward. This, says Kuhlen, is largely a social phenomenon which occurs because the teen-ager lacks social experience and *savoir-faire*, is uncertain of himself and others, and is often embarrassed. Thus, adolescent awkwardness is due not to lack of motor coordination but to lack of social sophistication.

LATER-AGE CHANGES IN MOTOR PERFORMANCE

The various locomotor and manual skills have already been acquired when the child starts school and during subsequent years undergo considerable refinement and improvement in ease of execution. Unfortunately, there is little experimental evidence on locomotor abilities beyond adolescence. We have all observed, however, that old age is accompanied by decreased speed of locomotion, shortened stride, shuffling and unsteady gait, and diminishing adeptness of fine movements. As was pointed out in earlier chapters, these changes presumably reflect certain neural alterations (motor pathways, cerebellum, etc.) as well as structural changes in joints, skeleton, and muscles.

Although we lack evidence on locomotor skills, literature on age changes in manual skills is more abundant. Most investigations in this area have been carried out by industrial psychologists, for it is well recognized that changes in motor performance are of practical importance to employers.

Despite the quantity of research, it is unfortunate that so many of the studies have been limited by using only reaction time and other such simple laboratory-type tests. Regardless of the shortcomings, let us see what we actually do know about age changes in motor abilities. For convenience, the available material will be subdivided into two groups involving (1) simple and (2) complex tasks.

Simple Motor Tasks

Reaction-time Studies. Reaction time has been a popular subject of study for many years, because the necessary tests are so simple and so easy to administer. The classic investigation in this area was carried out by Miles more than 20 years ago.
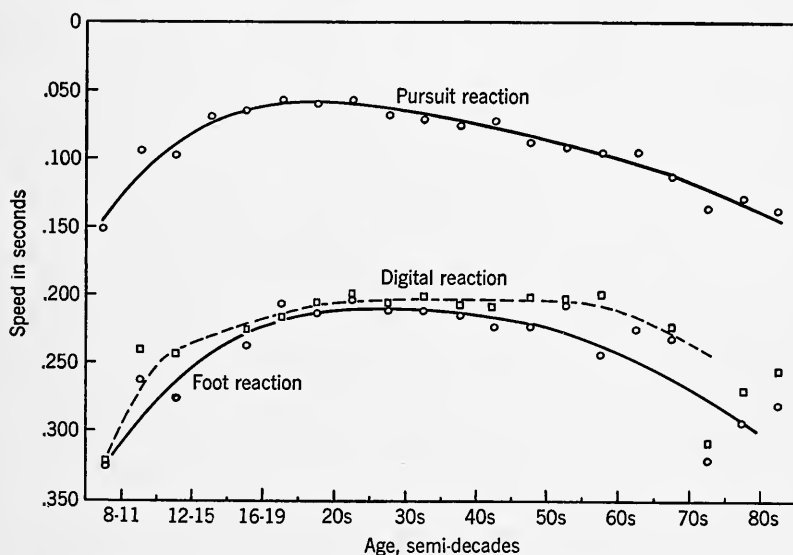
FIG. 48. Changes in reaction time with age. (*From Miles, W. R. Measures of certain human abilities throughout the life span. Proc. nat. Acad. Sci., Wash., 1931, 17. P. 631.*)

Miles's Study. Miles (1931) tested the speed of simple hand or foot reactions in response to an auditory stimulus as well as the speed of hand pursuit movements in several hundred subjects aged 8 to 80 years. His findings are graphically summarized in Fig. 48.

According to these data, speed of pursuit movements increases regularly into the late teens (around age 18) and holds fairly steady until the age of 30, when decline sets in, at first slowly and in later years more rapidly. The simple reaction times of forefinger and foot show similarly shaped curves rising to the age of 20 and subsequently leveling off. Instead of declining after age 30, however, these two curves remain fairly steady until around age 50, with reaction time of the forefinger, especially, holding up well

with age into the sixth decade. Beyond the age of 70, reaction time shows a cumulative decrement of roughly 25 to 33 per cent below the adult mean.

These curves are highly deceptive, however, since they fail to show the great overlapping in score distributions from age to age. We have commented on the great individual differences in almost every phase of human development and have pointed out that variability of scores tends to increase with age. In this specific instance, this means that while we find an average decline of 25 to 33 per cent in the performance of septuagenarians as compared with young adults, the performance of some elderly subjects is considerably higher. Actually about 25 per cent of the older subjects perform at a level which equals or surpasses the *mean* performance at the peak of maturity. In view of such overlapping, we join Miles in making a plea for considering employability on a basis of individual record rather than striking old people off the payroll merely because they happen to have been born 60 or 70 years ago.

Other Studies. Since the classic work of Miles, other studies have been carried out (among them Fisher, 1932; De Silva, 1936; Forbes, 1945). In general, investigators have obtained age curves for reaction time resembling those of Miles and showing little decline before the age of 60. Bellis (1932), however, who studied reaction time to light and sound in individuals aged 4 to 60 years, reports that the 50- to 60-year-olds required almost twice as much time as younger subjects. He observed little decline between ages 30 and 50 but a sharp drop in the sixth decade. Since his sample included only 10 cases at this age level, the large decrement is open to question.

De Silva (1936) supplied some data on motor reactions more closely akin to situations in everyday life, since his tests were made on automobile drivers. One of his tests measured the speed with which the driver raised his foot from the accelerator and depressed the brake pedal in response to a signal. The reaction-time curve generally resembled Miles's curve for foot reaction (see Fig. 48), reaching its peak efficiency in the mid-20's and declining gradually thereafter. The increase by age 65 amounted to 0.06 sec. over the time required at age 25. If we consider this finding in terms of a car speeding at 50 miles per hour, the increase in reaction time means that the car would advance an additional 5 ft. before the brake was applied.

Reaction Time and Conduction Rate of Impulses. The above data indicate an increase in reaction time in one degree or another as age advances. Possibly this slowing down of response is due to the slower conduction rate of neural impulses in the aged. Wagman and Lesse (1952), who studied one of the peripheral nerves (the ulnar nerve of the palm), found a decrease in conduction velocity of neural impulses beginning around the age of 60.

This is in harmony with the onset of decline in the reaction-time curves discussed above.

Reaction Times and Accident Rate. It has been frequently suggested that the lengthening of reaction time may be reflected in a greater number of personal injuries among older workers. After comparing reaction times of 536 railroad employees with accident records, Fisher (1932) stated that the age ranges which show the best reaction times also show the lowest accident rates, while the age ranges with poorest reaction time have the highest incidence of accidents. Perhaps because his conclusion sounded so logical, no one challenged his findings for almost a decade. At that time a very extensive survey, reported by Kossoris (1940), failed to support Fisher's conclusions. Kossoris examined the industrial accidents among 26,000 employees in four plants—two public utilities, one light manufacturing, and one heavy manufacturing. He found that the accident rate of the older workers aged 50 and over, whose reaction times were relatively slow, was considerably lower than the incidence in younger groups. Other research corroborates this finding and indicates that, although speedy reactions are unquestionably of value in many respects, they are no guarantee against accidents. The older worker may be slower, but he is also more cautious.

Simple Manual Reactions. Miles (1931) provided further evidence on speed of various manual responses such as rotation of the hand, reaching, grasping, and flexion-extension movements—all tests analogous to many of the fast, highly coordinated movements required by jobs such as assembly tasks. The graphs obtained were very similar to the curves shown in Fig. 48. Rising from low speed at the age of 8 to a peak around age 20, the curves level off with only slight change until the fiftieth year, when decline sets in. Again Miles observed great individual differences.

Rate of Tapping. Tapping is one of the simplest manual reactions. Ehinger (1931) studied the performance of a group of factory workers on this task. He noted an improvement in performance up to the age interval of 25 to 30 followed by a gradual decline to age 50, when performance was from 8 to 20 per cent below peak efficiency. Kubo (1938), who studied older subjects aged 70 to 100 years, reported that little if any decline in tapping rate occurs after the age of 70. Simonson *et al.* (1944) attempted to improve tapping rate in men aged 48 to 67 years by means of testosterone therapy, but the attempt was unsuccessful.

Complex Motor Tasks

Tests of Dexterity. Age changes in manual and finger dexterity have received their share of investigation, chiefly by industrial psychologists. Many of the studies have employed standard apparatus such as the Minnesota Manual Dexterity Test, the O'Connor Finger and Tweezer

Dexterity Test (Chase and Darley, 1934), and the Peg-Board Test (Kubo, 1938), in which the essential factor is the rate at which the individual can pick up pegs, pins, or other objects and insert them in designated places. Others have appraised the speed with which the subjects can assemble blocks (Miles, 1931), string beads, or cut out designs from paper (Ehinger, 1931). A review of these studies indicates that age changes in dexterity follow a course similar to the age changes in the simple tasks already described. Dexterity reaches a peak sometime in the 20's, levels off, and finally declines slowly to a point 10 or 20 per cent below peak performance by the age of 50 and more rapidly after 65. The range of individual differences is also similar; often 25 per cent or more of the older subjects surpass the performance of the average younger adult.

Job Experience and Amount of Decline. So far, we have noted that most studies point to some decline in performance in later years. One point which is frequently overlooked, however, is that job experience may delay or compensate for decreases in speed and dexterity. Miles and Miles (1943) cite some relevant evidence. They gave a cube-assembly test to persons ranging in age from 20 to 90 years, and, as might be expected, obtained the typical gradually sloping curve when manual dexterity was plotted against age. The important point, however, is that when they plotted the scores of only such older subjects as were actually engaged in jobs requiring rapid manipulation of parts, they found *no decrease* with age. These older subjects retained the performance level of young adults. In contrast to this group, older workers not so employed showed the typical decline curve.

Prolonged Work and Age. The motor tasks discussed so far have all been of short duration and consequently tell nothing about the endurance of subjects tested. Everyday activities normally demand not only ability to perform a given task but also ability to sustain this effort over a prolonged period. The problem of endurance, too, is of particular concern to applied psychology, for there exists today a general belief that older people have less endurance than the young, and such a belief raises barriers to employment.

Some relevant data are reported by Smith (1938). He required 155 males, aged 20 to 50, to assemble and disassemble two nuts and bolts continuously for a short period of 15 min. and later for a longer interval of 4 hr. Financial incentives ensured motivation for the otherwise dull task. The performance curves for the short and long periods were essentially similar, increasing to the age of 30 and then declining. The age decrement was much greater for the longer period, however. For the 15-min. period, the 50-year-olds dropped only 8 per cent below the peak level found at age 30, but for the 4-hr. period they dropped 15 per cent. Figure 49 illustrates the work output of the various age groups for successive half hours of the long

assembly period. The striking feature of these curves is their similarity in shape. The older subjects show neither a longer warming-up period at the beginning nor greater decrement near the end. Although their output is lower throughout the entire period, their endurance is just as great as that of younger subjects, as evidenced by the consistent pace from beginning to end.

Age and Proficiency in Various Skills. The peak of athletic performance is reached earlier in life than the height of achievement in many other fields of endeavor (compare with data in Chapter 12). Lehman (1951)
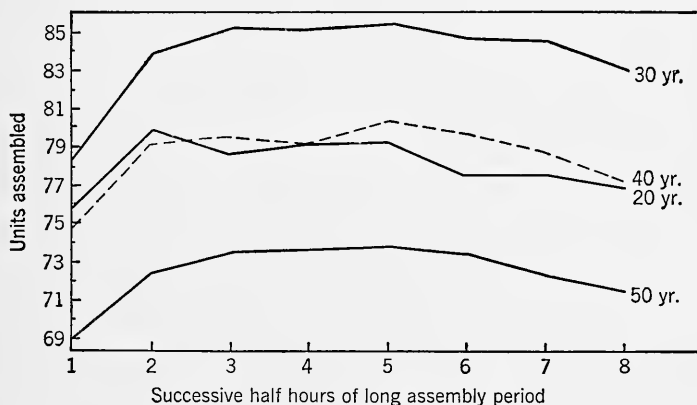
FIG. 49. Average production on nut and bolt assembly at ½-hr. intervals of the 4-hr. work period for the various age groups. (*From Smith, K. R. Age and performance on a repetitive manual task. J. appl. Psychol., 1938, 22, 303. By permission of the American Psychological Association.*)

made an extensive survey of the ages at which extraordinary skill has been most frequently exhibited in sports and games of various kinds. His findings are summarized in Table 4. Evidently the peak age for skills such as tennis and boxing coincides with the best years for other motor tasks, falling between the ages of 25 and 32 years. The peak ages of Olympic contestants range from 22 to 36, depending on the type of sport—for example, swimming, 22 years; gymnastics, 25; and horseback riding, 36.

Age Changes in Writing Skills. Writing involves a considerable degree of finger dexterity as well as eye-hand coordination. An interesting study of this highly overlearned skill was reported by Birren and Botwinick (1951), who tested a group of 554 subjects ranging from 16 to 89 years as well as 35 patients with senile psychoses aged 60 to 70 years. Subjects were presented with pages of digits or random words collected from newspapers and were instructed to "write these words as fast as you can but be sure I can read your handwriting." Table 5 records the speed of writing digits and words for various age groups.

According to Table 5, there is a considerable reduction in graphic speed

for both words and digits. Normal subjects over the age of 70 accomplished roughly one-third as much in a given time as did the adolescents and young adults. This decrement is therefore somewhat larger than the decreases found in most physiological and psychological functions. Furthermore, scarcely any overlap existed for the score distributions of the oldest and the youngest subjects. Patients who had senile psychoses, but

TABLE 4. APPROXIMATE AGES AT WHICH EXTRAORDINARY SKILL HAS BEEN EXHIBITED MOST FREQUENTLY BY VARIOUS PERFORMERS*

Performer	Age, years	Performer	Age, years
Professional baseball players	28	Automobile racers	27
Professional pugilists	27	Corn-husking champions	29
Golfers	32	Amateur bowlers	32
Tennis players	27	Duckpin bowlers	33
Amateur roller skaters	17	Rifle and pistol shots	33
Ice-hockey professionals	27	Professional billiardists	28
Professional football players	25	U.S. Olympic contestants	22 to 36

* Based on data of Lehman, H. C. Chronological age versus proficiency in physical skills. *Amer. J. Psychol.*, 1951, **64**, 161–187.

TABLE 5. SPEED OF WRITING DIGITS AND WORDS IN SUBJECTS 16 TO 89 YEARS OF AGE*

Age	Digits per second			Words per two minutes		
	M	σ	N	M	σ	N
16–19	1.62	0.24	189	45.2	5.2	190
20–29	1.62	0.26	57	48.0	6.6	60
30–39	1.63	0.39	53	47.1	9.7	53
40–49	1.29	0.40	49	38.0	12.0	52
50–59	1.03	0.41	41	29.4	12.0	42
60–69	0.82	0.32	66	22.0	9.7	68
70–79	0.57	0.20	55	16.5	7.3	55
80–89	0.49	0.20	37	15.2	7.0	34

*From Birren, J. E., and Botwinick, J. The relation of writing speed to age and to the senile psychosis. *J. consult. Psychol.*, 1951, **15**, 245. Quoted by permission of the American Psychological Association.

who were otherwise similar to normal senescents in age, sex, and education level, exhibited a further reduction in writing speed, and their scores were not only significantly lower than those of younger groups but also lower than the scores of normal senescents. These patients include only cases in which either arteriosclerosis or senile brain changes were considered responsible for the psychotic condition. The writing of many of the senile subjects had the characteristics of drawing rather than of script.

The writing-speed decrements of the normal aged cannot be attributed to visual defects, since large-size type was used, and reading glasses were provided. The investigators believe that a number of factors may be involved: changes in the brain, arthritic involvement of the fingers, and possible muscular changes in the hands and fingers.

Style of Writing and Age. The only good study on age changes in style of handwriting was contributed by Bois (1936). Bois requested acquaintances, friends, and students to submit specimens of their handwriting at different ages. He managed to get four or five samples, scattered over a 10- to 25-year period, from six subjects and four samples, scattered over the interval from age 14 to age 40, from four other subjects. He devised a scoring battery based on nine indexes such as size of letters, intervals between letters and between words, length of cross strokes, and constancy of pressure. He concluded that during the course of life, from graphic maturity at the age of 10 through adulthood, the individual shows only slight fluctuation in graphic scores. In every instance where large fluctuations existed, the extreme variations coincided with periods of severe physical illness or with some traumatic experience. In general, variations disappeared when the physical or emotional crisis had passed. It seems, therefore, that "once a poor writer, always a poor writer." If legible script is a desirable skill, then it must be acquired relatively early in life.

Component Analysis of Motor Tasks

In all studies of motor performance so far discussed, the investigators have been concerned solely with over-all achievement as indicated by time scores or units of work accomplished at different ages. In recent years, however, a psychological team working at Cambridge University has made what appears to be a very fruitful approach by analyzing test tasks according to a number of components, scoring each separately in order to determine which components hold up with age and which deteriorate. Most of this work has been summarized by Welford (1951) in his book *Skill and Age.* Although this type of analysis is still in the exploratory stage, and the number of cases tested is not large, the results obtained are so challenging and, if supported, of such great importance that it is well to examine them. All tasks involved are fairly complex.

Grid-position Matching. In this experiment, 51 subjects were required to move a pointer to a locus on a graph paper corresponding to a spot indicated on another graph. As soon as the move had been made, the spot on graph 2 automatically shifted and the subject had to match the new location again on graph 1. The test thus involved a series of moves whose various components were measured separately.

Figure 50 illustrates the total number of recorded events analyzed ac-

cording to age groups together with an analysis of the total events according to three components: number of successes, large errors, and small errors. This figure needs careful study. It is readily noted that the 20- to 30-year group recorded a considerably larger number of events than the two older groups of 31 to 50 and 50 to 80 years—in fact, almost 50 per
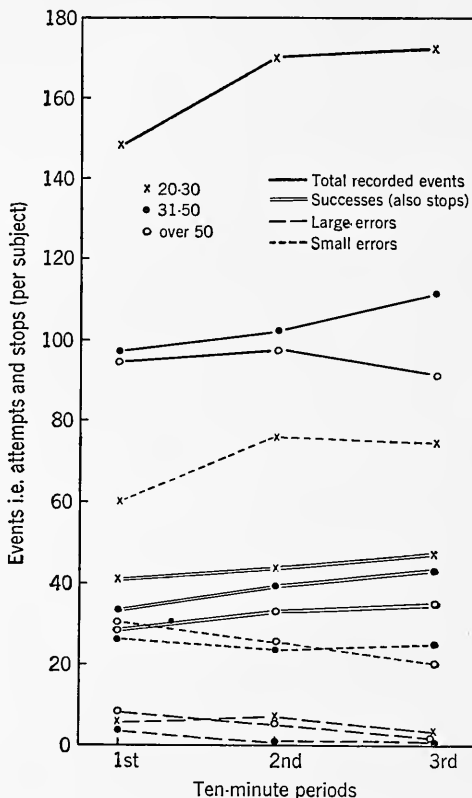
Fig. 50. Analysis of recorded events on a matching performance task. Note that the youngest subjects recorded substantially more events than the older ones but that the high score was due primarily to the presence of many small errors. (*From Welford, A. T. Skill and age. New York: Oxford, 1951. P. 36. By permission of the publishers.*)

cent more. When we examine the less obvious accuracy scores, however, we see that there is no significant difference between any of the age groups for number of successes or for large errors. The youngest subjects, however, made almost three times as many small errors as the oldest subjects, indicating that their high over-all output was achieved at the expense of accuracy and consisted of many small mistakes.

Further analysis revealed that the total time required for a sequence of matchings was much greater for the oldest subjects. The factor that contributed most to the larger total was the time required to move on to a

new situation, that is, the time between successful completion of one move and the beginning of the next. Furthermore, this delay was found to be due to *increased caution* exhibited by the older subjects in positioning the pointer for the next move. Other time scores such as time involved in making large or small errors showed no significant age changes for the entire 20- to 80-year range. Thus we may conclude that the grid-matching performance of older subjects tends to be slower and more deliberate than that of younger people but that it is considerably more accurate.

Target Throwing. Members of another group of 84 subjects, aged 15 to 59, were each required to throw 50 loops of chain at a target made of intersecting strips of fiberboard arranged to form 49 3-in.-sq. boxes placed flat on the floor at a distance of 8 ft. from the subject. They were told to aim for the center box, or "bull." Measurements were made of the time required to throw all the chains, of accuracy, and of the direction of inaccuracies with respect to the bull. No significant deterioration in time, accuracy, or direction of inaccuracies was observed; in fact, the older subjects tended to be *more accurate* than the younger.

The test situation was then complicated by requiring the subjects to throw the loops over a horizontal bar, midway between subject and target, at an elevation of several feet. Again, no significant differences between age groups emerged, but this time there was a slight tendency for inaccuracy on the far-near dimension to increase with age. A further complication was then introduced. A screen was placed in front of the target and a mirror behind it in such a way that the subject had to depend on the mirror image in order to aim. This complication produced considerable impairment of both accuracy and time scores in the older subjects. The decreased accuracy became apparent in the greater number of errors in far-near dimensions and in the older subjects' difficulty in making corrections for errors, as evidenced by a tendency to throw successive chains toward the same part of the target (*i.e.*, "rigidity" of older performers). Since the simple motor task of throwing over a screen was the same as throwing over the horizontal bar, it is clear that the performance decrement was due to complication of the perceptual task and not to failure of effector mechanisms.

On a basis of these findings, we may conclude that older subjects may exhibit little or no impairment in time or accuracy in tasks involving a simple relationship between perceptual and motor functions but may show considerable impairment in both time and accuracy when the relationship becomes so complex that the subject needs to engage in mental "manipulation" (such as that involved in reversing the far-near dimension in mirror) before making a motor response.

Tracing Figures. In another situation, 65 subjects ranging in age from the 20's to the 70's were each presented with a large metal plate in which

the digits 1 to 10 were inlaid in brass. They were requested to trace the
digits with a stylus as quickly as possible. Next, they were given another
plate with mirror-image digits and were asked to repeat the tracing. Next,
the first plate was used again, and following this, the entire procedure was
repeated, but the subjects were required to write the digits and their mir-
ror images on a sheet of paper instead of tracing them.

Analysis revealed that tracing time increased markedly with age; writ-
ing time also increased, but less markedly. Accompanying the increase in
time scores was a very large increase in variability among subjects, as
indicated by the standard deviations recorded in Table 6. Further analysis
of the tracing performance indicated that the older subjects were much
slower than the younger on the *first* trial in tracing reversed figures and
even slower on the *first* attempt at writing the mirror images of the digits.
Thus it becomes clear that older subjects were delayed when *initially* con-
fronted with a new task or variation of a problem. These findings are con-
sistent with the results of the grid-matching experiment, in which older
subjects required more time in dealing with *changes* in the display. Anal-
ysis of error scores indicated that errors in tracing were greater among
younger subjects, falling off rapidly in the 40's to reach a minimum in the
60's and 70's. Again, these findings are in line with the grid experiment and
indicate that older people tend to be slower but more accurate than the
young.

In discussing the various experiments, Welford (1951) attempts to de-
termine the mechanisms responsible for the age changes in the specific per-

TABLE 6. AGE CHANGES IN STANDARD DEVIATIONS OF TIMES TAKEN FOR 15 RUNS OF
10 FIGURES (1–10)*

Age range	N	Standard deviation, sec.
20–29	12	42
30–39	10	51
40–49	9	92
50–59	14	89
60–69	14	100
70–79	6	174

* From Welford, A. T. *Skill and age.* New York: Oxford, 1951. P. 65. Quoted by
permission.

formance studied. He has presented evidence indicating that the observed
changes were due not to deterioration of peripheral mechanisms such as
receptors or effectors but to changes in the central nervous system. He
suggests that the locus of these changes is in the central brain mechanisms
concerned with the process of organizing incoming stimuli and outgoing
responses. As we have seen (Chapter 3), both structural and functional

changes do occur in these neural mechanisms in old age. The breakdown of the central mechanisms may express itself in different ways in different tasks, for example, in reduction of speed or in decreased precision. The results obtained by Welford certainly suggest some such process.

Aiming Performance. Another recent experiment by the psychological team at Cambridge, not mentioned in Welford's book, is described by Szafran (1951). Forty industrial workers, aged 20 to 60, were given a task of locating targets with a pointer. Five separate time measures were recorded and a component analysis carried out. The mean over-all time per target increased consistently and substantially with age, with the oldest subjects scoring roughly twice as high as the youngest. However, the component analysis again revealed that the time-consuming factor was the *initiation* of a new response. This required about 60 per cent more time for persons over 40 than for those under 40; for individuals over 50, the time lapse was still greater. This is in line with the previous experiments.

It was also found that reducing vision by means of goggles impaired the performance of older subjects more than that of younger ones. This agrees with an observation by Welford (1951) that in throwing rings at a target older subjects show a greater tendency to watch what they are doing than do younger individuals.

General Comments. Most of the evidence to date points to an increase in efficiency of motor performance throughout childhood, adolescence, and early adulthood and to a differential decline with advancing age. This decline varies in both time of onset and rate, depending on the type of task, the complexity of the task, and other factors. One of the most conspicuous findings is the relative homogeneity of the young as compared with the large individual differences of the older subjects.

For employment purposes, it should be recalled that 25 per cent or more of the older group surpass the *average* young adult in performance. This means that retirement should be based on individual ability rather than on chronological age. Pensioning employees as a group at the age of 50, 60, or 65 is inconsistent with the findings of these studies and is not in the best interests of either the individual or his society. We shall have more to say about this in the chapter on "Social Development."

Another important implication of the few studies reviewed is the great need for more research along the lines followed by the Cambridge group. If older employees are to be retained in industry beyond the present retirement age, then it is essential to know where and in what kind of job they may continue to function with the greatest efficiency. Present evidence suggests that they may be more effective in work that stresses accuracy above speed, for example, or in jobs demanding few shifts from one approach to another. Perhaps in this connection early education may be made more conducive to flexibility of outlook, for we do not yet know

whether this increasing rigidity is an inevitable consequence of age or whether it results from the routines imposed by society. Research is needed in this area also.

A further point to be considered is the large number of errors made by the younger subjects. Such errors can be—and without doubt are—costly to the employer. There are many instances where a large over-all output with many errors fails to outweigh a smaller output with relatively few errors. Job experience may in many cases offset the age decrement, and, where decrements occur, they may be reduced through such technical improvements as better lighting and better physical arrangement of the plant to eliminate or minimize bending, stooping, or standing for long periods. Frequent rest periods would also be of value.

As yet, scarcely any experimental findings have been applied in the interests of the older worker. As more and more of our population moves into these age brackets, however, it will become an economic necessity to extend their industrial lives as well as the life span. Moreover, as we shall see presently, the adjustment and well-being of the aged are at stake, for they depend to a considerable degree on the subject's own evaluation of his usefulness to society.

SENSORY DEVELOPMENT. I. VISION AND HEARING

So far, we have dealt with the body itself—the neural, glandular, skeletal, muscular, and motor aspects of development—and have not been particularly concerned with the environment. The only way in which the external world can affect the body is through the media of the senses. From the point of view of adjustment, perhaps the most important are the senses of vision and hearing. Most of the research in this field has also concerned these two senses. We shall therefore examine them first in the present chapter and follow up with a discussion of the other senses in Chapter 8.

VISION

Phylogenesis

Invertebrates. To one degree or another, all organisms are sensitive to light—indeed, it is such a widespread phenomenon that some have considered it to be one of the properties of living cells. Single-celled organisms such as the amoeba are so constituted that their entire bodies respond to light. They avoid strong light, although their reactions are slow. While the amoeba's entire body is sensitive to light, certain other protozoa such as the euglena possess a structure known as an *eyespot*, which is considered the earliest precursor of the human eye. This spot of reddish pigment is located at the base of the flagellum, or whiplike process, at the anterior end of the euglena. By means of it, the organism is able to respond to the absence or presence of illumination.

Although not invariably present, pigment spots are common in the lowest multicellular forms such as the coelenterates. In the medusa, for example, instead of a single eyespot, clusters of pigment spots are found along the margin of the umbrella. When these are destroyed, the medusa can no longer make light-oriented movements. Further evolution is indicated in another coelenterate, the jellyfish, which exhibits pigment spots covered by a lenslike structure which serves to focus the light on the underlying pigment cells.

As we ascend the scale to the flatworms, we find certain marine forms which possess paired pigment spots situated in immediate relation to the

"brain." These may be thought of as flatworm eyes. Other flatworms have two clusters of pigment cells grouped around endings of the sensory nerves of the head.

Appearance of Compound and Simple Eyes. From this point on up the phylogenetic scale, eyes may be said to evolve in two directions. First is the multiplication of light-sensitive pigment spots which eventually form the compound eye so characteristic of arthropods, especially insects. This compound eye consists of several or even hundreds of closely packed cylindrical units, or "eyes" (*ommatidia*), each with its own lens and its own nerve ending. Such an eye is excellent for exploratory purposes,
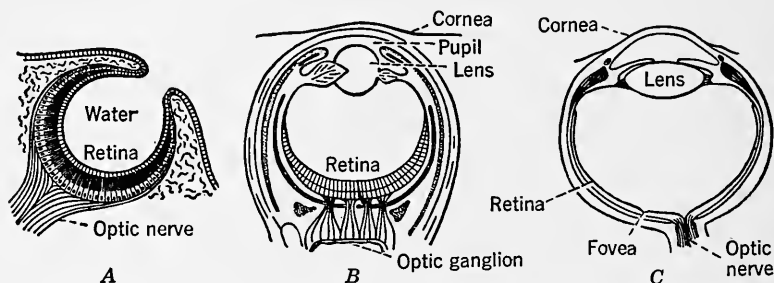
FIG. 51. Main stages in the evolution of the eye. *A*, the eye of the nautilus. This eye has no lens; hence the focus is fixed. *B*, the eye of the octopus. Here there is a lens which provides a focus by being moved toward or away from the retina. *C*, the human eye, in which focusing is accomplished by changes in the curvature of the lens. (*After Conn and Gegenbaur. From Munn, N. L. Psychology. Boston: Houghton Mifflin, 1946. P. 33. By permission of the publishers.*)

since it enables the organism to see well in all directions at once and is acutely sensitive to movement of objects. The second direction of evolution is the development of the so-called simple eye with one retina. Its earliest precursor is found in some of the annelids, for example the earthworm, in which the pigment spot is located at the bottom of a small pit. With this kind of structural arrangement, however, effective stimulation can occur only when light comes from the direction opposite the pit.

Evolutionary Changes in Simple Eye. The next forward step involves the enlargement of this pit to form a spherical cavity, the optic cup, whose bottom is lined with a layer of light-sensitive pigment cells which may be considered a primitive retina. This type of water-filled cavity is characteristic of some of the lower mollusks such as the nautilus of the cephalopod class. This kind of eye is shown in Fig. 51*A*. The next two major advances also occur among the cephalopods. In some of these, the opening of the optic cup is fitted with a spherical lens. It is of a nonadjustable focus, however, so that a clear image is possible only when the object is at a fixed distance from the eye. A further advance is seen in the octopus and the cuttlefish, two other cephalopods, which have an eye closely resembling

those of vertebrates, as illustrated in Fig. 51*B*. This eye is partly surrounded by a strong, opaque tunic analogous to the sclerotic layer of the human eye. The front part of this tunic forms the transparent cornea. Behind the cornea is the iris and a biconvex lens which may be moved by muscles to or away from the retina. Such a change in position of the lens provides a mechanism by which objects at various distances may produce clear images on the retina.

Vertebrates. One of the main differences between the most highly developed eye of the mollusks and the vertebrate eye is the presence of an inverted retina in the latter. Mollusks have retinas whose photoreceptors face the source of light; vertebrates, on the other hand, have inverted retinas, so that the light has to pass through a number of retinal layers before stimulating the photoreceptors. There appears to be no explanation for the sudden appearance of this phenomenon in the vertebrates. In addition to this inversion, the retina of vertebrates undergoes a number of other changes as the phylogenetic scale is ascended. First, there is an increase in the number of lateral connections, or association neurons, which serve as interconnectors among different receptors in different parts of the retina, thus producing in the higher vertebrates a retinal network fairly similar to the neural network of the central nervous system. Secondly, there is a development in the retina of certain areas of increased sensitivity to light. These areas are not particularly well developed in either the fishes or the amphibians, but in birds we find the formation of a *fovea*, a small pitlike depression in the retina, which is an acutely sensitive area having the clearest vision. Two or three fovea may be found in certain birds. This development in birds is accompanied by an increase in visual capacity.

Changes also occur in the lens. In fishes and amphibians, the lens arrangement continues to resemble that of the cephalopods, in which focusing is accomplished by movement of the lens to or away from the retina. In reptiles, however, changes in the lens curvature appear—that is, a bulging of the lens for near objects and a distension or thinning of the lens for far objects. This mechanism is poorly developed in reptiles, but at the level of birds, rapid accommodation of the lens to varying distances has been achieved. Birds' eyes are highly developed and, in general, possess the main features of the human eye.

Changes in Location of Eyes. In addition to structural changes, the eye, during the course of evolution, changes its location, moving away from the side of the head toward the front. In lower vertebrates, the eyes are located in the side of the head, and each eye thus provides a different or slightly overlapping view. Beginning with the monkey, the eyes shift forward to view the same visual field. This development is especially important, since it is the basis of depth perception. Accompanying this change

in position, the eyes become more mobile, making convergence possible and also enabling the animal visually to pursue moving objects without moving the whole head. The optic nerve pathways also change. In vertebrates below the mammals, the optic nerves cross to the opposite side of the brain so that the left eye, for example, is represented in the right hemisphere. Beginning with the rodents, however, a very small part of each eye is represented in the same side of the brain. In monkeys, about a third of each eye is represented in the same side, while in human beings, the left half of each eye goes to the left hemisphere while the right half of each eye goes to the right hemisphere. Thus one side of the brain receives impulses from both eyes, making possible the fine coordinated movements that human eyes are capable of.

Phylogenesis and Visual Functions. Comparative psychologists have conducted numerous studies of visual processes at various phylogenetic levels. Many of these have been inconclusive because appropriate controls were not made. Only a brief summary of this work is possible here (see Maier and Schneirla, 1935). In general, it may be said that all organisms from the unicellular forms up respond in some degree to brightness. Furthermore, all organisms, with the possible exception of the lowest invertebrates, respond to the movement of objects. Organisms such as insects, possessing compound eyes, are especially sensitive to moving stimuli.

Pattern and Size Perception. Perception of the pattern and size of objects has also been widely studied. There is some evidence that certain of the mollusks, especially the cephalopods, are capable of a crude size discrimination, but whether they can discriminate patterns is debatable. It is only in those arthropods which have compound eyes that good evidence for both size and pattern discrimination has been found. Pattern perception in vertebrates, with the possible exception of fishes, is good. In certain birds, visual acuity is so highly developed that it can be equaled only by some of the highest primates.

Color Vision. The question of the absence or presence of color vision in invertebrates and vertebrates is complicated by the fact that many investigators have failed to equate colors in brightness values. Evidence makes it quite clear, however, that no organisms below the arthropods have color vision. Whether arthropods have color vision is also a moot question, since brightness controls in the experiments were inadequate. In vertebrates, too, only a few studies have been done in which animals have discriminated differences in wave length independent of brightness. There is clear evidence for color vision in fishes, birds, rodents, and primates. It is highly probably that some of the other vertebrates also possess color vision to some degree.

The Human Eye

The essential anatomic characteristics of the human eye are shown in Fig. 51*C* and in greater detail in Fig. 52. The cross-sectional view in Fig. 52 indicates that the human eye is constructed much like a camera, with a lens system which focuses the light on a sensitive film, the retina.

Choroid and Sclerotic Coats. In addition to the retina, the wall of the eye has two coats, or tunics, called the *choroid* and *sclerotic layers*. The
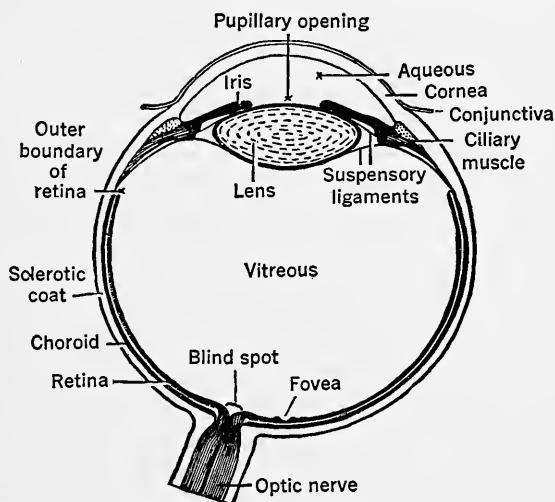
FIG. 52. Schematic diagram of the human eye. (*From Warren, H. C., and Carmichael, L. Elements of human psychology. Boston: Houghton Mifflin*, 1930. *P.* 80. *By permission of the publishers.*)

choroid, which lies next to the retina, is a highly sensitive vascular layer containing a fine network of small veins and arteries. It is dark in appearance because of the presence of many pigment cells. Its function seems to be to prevent light from coming through the sides of the eye, thus restricting its entrance to the pupillary opening. It is also believed to diminish the amount of internal reflection of light, thus preventing the multiplication or blurring of the retinal image. The third layer, or external covering, is the sclerotic coat, which is made of thick fibrous tissue. The posterior $\frac{5}{6}$ of this coat is opaque, but the front $\frac{1}{6}$ is transparent and is called the *cornea*.

Lens and Accommodation. Let us now look briefly at the internal structure of the eyeball. Immediately behind the cornea is the *lens*, a transparent, biconvex structure which is transparent when it is in good health. "Floating" this lens into position are two fluids: the *aqueous humor*, filling the space in front of it, and the *vitreous humor*, behind it.

The main function of the lens is to adjust its curvature so that objects located at various distances from the eye will have their images sharply focused on the retina. The ability of the lens to adjust for objects at varying distances is called *accommodation*.

Iris. Suspended by muscles behind the cornea but in front of the lens is a circular, colored diaphragm, or disc, called the *iris*. In the middle of the iris is a circular opening, the *pupil*, through which light enters the eye. The iris itself contains a great many pigment cells which give the eye its blue, brown, or green color. The iris is equipped with two sets of smooth muscles, the action of one set antagonistic to that of the other. One of these sets is arranged circularly around the pupil, while the other radiates from the pupil outward. This arrangement enables these muscles to regulate the amount of light entering the eye. When the eye is stimulated by a bright light, for example, the circular muscles contract and thereby diminish the size of the pupil; on the other hand, when illumination is low, the radial muscles contract, thereby increasing the size of the pupillary opening. Distance as well as brightness may affect pupil size, so that near objects produce a constriction of the pupil, while far objects result in dilation in an effort to admit more light, thus clarifying the remote object. The circular and the radial muscles are controlled by the parasympathetic and sympathetic divisions of the autonomic nervous system, respectively. We have no voluntary control over changes in pupil size.

Retina. The retina is the sensitive "photographic film" of the eye—the structure on which the images of the objects we look at are directed. In reality, it is a part of the brain, connected with the brain proper by the optic tract and possessing the structural and functional characteristics of brain tissue. As has already been noted, the retina is the innermost coat of the eyeball. In the center of the retina is a yellowish area known as the *macula lutea*. In the middle of this macula is a tiny pit called the *fovea*, which is the center of direct vision. Whenever the eye fixates on an object, the image of that object is projected into the foveal region. This region is the area of greatest acuity, or clearness of vision. Whenever we wish to see anything especially clearly, for example, when we are reading, we continually move the eyes so that the light from the object will strike the fovea. A short distance lateral to the fovea is a whitish area, the *optic disc*, which is the exit point for the optic nerve. Since no receptors are present in this region, light striking it will not elicit any sensation. It is therefore known as the *blind spot*.

Rods and Cones. The rods and cones, so named because of their shape, are the receptor organs of the eye. The outer parts of these receptors contain a pigment—*rhodopsin*, or visual purple, in the rods and *iodopsin* in the cones. These are believed to be broken down in the presence of light and regenerated in its absence. Of the two kinds of receptors, the rods are

much more numerous, especially in the peripheral areas of the retina, decreasing as the fovea is approached. In the fovea, no rods can be found; only cones seem to be present. Whereas the rods increase in number toward the periphery, the cones decrease in number in this direction.

Rods and cones differ in their sensitivity to light. Rods can respond to very low intensity of illumination and are thus the mechanisms responsible for dim-light vision. Cones, on the other hand, are more insensitive, requiring high intensities of stimulation, and thus function in daylight vision. Furthermore, the cones are the mechanisms necessary for color vision.

Early Developmental Changes in Vision

The eye develops as an outgrowth of the forebrain. Sometime around the third week after fertilization a saclike structure, or vesicle, is formed at the side of the brain. This vesicle slowly grows outward, leaving behind a stalk which connects it with its point of origin and which later becomes the optic nerve. The vesicle at the end of the stalk undergoes a series of changes. The outer part thickens and folds inward (evaginates), eventually forming the lens, while the part nearest the stalk differentiates to form the various layers of the retina. From the tissues surrounding the eye, other structures such as the cornea, eyelids, and eye muscles develop. By the age of 5½ fetal months, all the retinal layers are present, but the structures in which we are most interested—the rods and cones—although present, are very small, immature, and bear little resemblance to those of adults. According to Zetterström (1951), developmental changes in the retina continue from this period onward, until at birth the peripheral parts of the retina have virtually attained their definitive appearance. Zetterström states, however, that differentiation of the central regions around the fovea continues for at least 16 weeks after normal birth.

Prenatal Vision. Although we know the approximate times at which the various structures of the human eye appear, we still do not know whether these structures are capable of function at these times or even at birth. The visual mechanisms may be ready to function even before birth, but the nature of the prenatal environment is such that true vision is impossible. A number of studies have been done on prematurely delivered fetuses (see review in Carmichael, 1946), but the results are conflicting. There is some evidence that infants born 2 months before term can differentiate between light and darkness. We also have reports that shining a bright light into the eyes will result in constriction of the pupil. On the other hand, there are also studies in which such visual reactions were not noted, so the problem is as yet unsolved.

Literature on postnatal development of vision is vast, and therefore only the most important of the many studies which involve the various visual processes can be cited.

Electrical Activity of the Retina. A Swedish investigator, Zetterström (1951), made use of the new developments in the field of electrophysiology to give us for the first time some information concerning the functional state of the retina of infants from birth to the age of 1 year. Since this study is of such great importance in this field, it will be discussed in some detail. Zetterström placed an electrode on the cornea and another on the forehead of the subject. With this arrangement, he was able to record electrical changes in the retina when the eye was stimulated by light. Such a record is called an *electroretinogram*, or ERG. He used this method to study the ERG of 35 normal, healthy newborn infants and subsequently carried out follow-up studies by intermittent tests over a period of a year. Perhaps the most startling finding was that the newborn infants showed
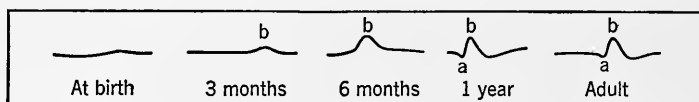
FIG. 53. Development of the *A* and *B* potentials of the electroretinogram during the first year of life. (*After Zetterström, B. The clinical electroretinogram. IV. The electroretinogram in children during the first year of life. Acta. ophthal., Kbh., 1951, **29**, 295–304.*)

no ERG reaction or only a slight nonmeasurable rise in the base line following each light flash. Using a very bright light had no greater effect at birth than a light of moderate intensity. The ERG records for the year are shown in Fig. 53. Examination of this diagram indicates that the ERG of the newborn infant is quite different from that of an adult. The adult ERG is characterized by a slight negative wave (*A* wave) and a large positive wave (*B* wave); no such elements are seen in the neonate's record. A study of neonates at 3 or 4 days gave the first indication of a distinctly positive *B* wave, as yet so small as to be unmeasurable. From this time on, however, the *B* wave gradually increased in size with age, until at 12 months it was of adult size. Furthermore, the *A* wave made its first appearance at 1 year and not before. Thus, it is only at the end of the first year that the ERG resembles that of the adult. Granit (1947), who analyzed the components of the ERG on the basis of various experiments, believes that the *A* wave is due to receptor activity of rods and cones and that the *B* wave is the result of neural activity in the optic nerve.

In attempting to account for the absence of the ERG in the neonate, Zetterström suggests that the chemical substances in the receptors, for example, visual purple, may be in a functionally inactive form at birth and so may produce no ERG when a light is flashed into the eye of the neonate, but that the substances require some exposure to light before they become active. Thus, after 3 or 4 days, the first sign of activity appears in the slight *B* wave. This view seems reasonable, since if visual

purple or other light-sensitive substance were absent or nonfunctional, receptors would be unable to convert the light energy into neural activity, and thus no ERG would be observed. However, this does not mean that the newborn infant is insensitive to light. Activity may be present but not great enough to be picked up by the recording techniques available today. All we can safely say is that the retinal activity of the newborn infant is at a level considerably below that of the 1-year-old or adult and that it progressively increases to attain adult level around the end of the first year.

Simple Reactions to Light. The fact that certain visual reflexes can be elicited in the newborn infant seems to indicate that the organism is sensitive to light, at least to some degree. One of the more extensively studied of these responses is the pupillary reflex. Sherman and Sherman (1925), who investigated age changes in this reflex from immediately after birth to 15 days, observed that if a light of a certain strength was flashed into the eye of the neonate just after birth, the neonate maintained a fixed stare. If the procedure was repeated about 3 hr. later, a very slow contraction of the pupil resulted. A repetition of the procedure at intervals of a few hours produced a gradual increase in the speed and amount of pupil contraction, until by the age of 30 hr. a prompt pupillary reaction was elicited. The intensity of light required to evoke a reflex also decreased throughout the 15-day period studied.

Other visual reactions that can be observed in the neonate are startle reactions, closing of the eyelids, and the *eye-neck reflex*, which is characterized by a throwing back of the head when a light is flashed into the eye. Whether these reactions will be elicited or not in specific cases seems to depend on the intensity and duration of the stimulus. All responses appear shortly after birth. The fact that these reactions are difficult to elicit immediately after birth but become progressively easier to arouse seems to parallel the changes in ERG which were mentioned earlier.

Eye-movement Responses. A number of eye movements have been investigated in infants, among them fixation of the eyes on an object and pursuit of a moving object. It is generally agreed that ability to fixate on a light is present at or shortly after birth (Sherman and Sherman, 1925). However, this early fixation is not well coordinated, and one eye often fixates on the object while the other turns in some other direction. Nevertheless, coordination develops rapidly, so that by the time the neonate is 2 or 3 days old, he is able to make almost perfectly coordinated movements. Although ability to fixate on a single light is present early in life, it is some time before the infant can do so quickly and before he can fixate on a number of objects in turn. Gesell and Thompson (1934) believe that this ability is achieved about the fourth week.

Pursuit Movements. Studies of pursuit movements are numerous. The various investigators, however, fail to agree on the precise time at which this ability first appears, and estimates range from several minutes after birth (McGinnis, 1930) to 33 days (Jones, 1926). In most of these studies, the time falls somewhere within the first week. McGinnis, whose study was well controlled, observed that although pursuit movements were present during the first week, they were only partial and were broken up by many movements in the opposite direction. It was only around the third or fourth week that well-sustained and primarily unidirectional eye movements could be observed.

So far, pursuit movements have been discussed in general. It has been demonstrated, however, that the ability to follow a horizontally moving light precedes ability to follow vertical motion. Both of these precede the ability to pursue a circularly moving light (Jones, 1926; Morgan and Morgan, 1944). Ability to follow a moving, three-dimensional object develops sometime later. Shirley (1931) reported that infants were able to follow the movement of a steel tape in a horizontal direction at a median age of $4\frac{1}{2}$ weeks, in a vertical direction at 9 weeks, and in a circular direction at 10 weeks. Pursuing the movements of people has been reported at 8 weeks.

Color Vision. A problem which has intrigued research workers in child psychology for many years is whether newborn infants can discriminate color or whether color discrimination develops with increasing age. In the 1880's, Preyer reported that at birth infants could differentiate only light from dark and that color discrimination was absent until the third or fourth year. The first real experimental attack on this problem was not made until 1926, however, when Peiper reported a study of four premature infants.

Relative Brightness Values of Colors. It has been known for many years that under daylight conditions the brightest colors of the spectrum are the yellows and reds but that in twilight the blues and greens are the brightest (*Purkinje shift*). Peiper hoped to determine whether the same relative brightness values of colors held for infants as for adults. To find an answer, he made use of the observation that a strong light causes the infant to throw back his head (the eye-neck reflex), but that as the light is reduced a point will be reached at which no reflex is elicited. Peiper then used red, green, yellow, and blue lights, gradually reducing the intensity of each until no eye-neck reflex resulted. The intensity values at which the response failed to occur were used as an indicator of the brightness value of each color. He reported that under daylight vision, yellow had the greatest brightness value, while under twilight conditions, blue was the brightest. These findings are the same as for adults, and consequently Peiper con-

cluded that the brightness of colors appeared to be constant regardless of age.

Since the Purkinje shift is related to the functioning of rods and cones, and since it is absent in color-blind people, Peiper reasoned that the presence of a Purkinje shift in infants indicated that they possessed color vision. His claims have been severely criticized, however, on the grounds that the measure of response which he used was subject to a wide margin of error, that not all of his cases gave evidence of any Purkinje shift, and that in those cases where the Purkinje shift did occur, it was not large enough to be statistically significant. Another investigator (Smith, 1936) also studied the Purkinje phenomenon, but again the results are open to criticism. Consequently, at the present time, it is impossible to state whether the relative brightness value of colors for infants is or is not similar to that of adults. The marked differences in ERG patterns suggest that such similarity may be lacking under the age of 1 year.

Does Color Vision Exist in Neonates? One of the main problems in the research on color vision consists of being sure that the subject is discriminating color differences and not brightness differences. Research has shown that color-blind people can pick out various colors when there are also differences in brightness, but as soon as the colors are equated for brightness, ability to discriminate color ceases. The particular problem involved in demonstrating that color vision actually exists in infants is that, although we may equate all colors for brightness according to the adult standards of the experimenters, we can never be sure that these colors will be of equal brightness for the infant eye. Many of the studies of color vision in infants have assumed that brightness values for infants are the same as those for adults. As the above data indicate, however, this assumption may not be valid.

More than a dozen studies of color vision in neonates have been reported. Only the more important will be mentioned here (an excellent review of this topic is given by Munn, 1938). In general, all these studies, except some very early reports, indicate that color vision is present to some degree in infants. Since all these studies have equated brightness for the infant and adult eye, however, the results are open to doubt. One of the more interesting of these investigations was carried out by Chase (1937), who projected a small moving spot of color over a background of another color, both colors being equated for brightness for the adult eye. The assumption was that if the infant could follow the moving spot, color discrimination was present. Chase reported that infants as young as 15 days made pursuit movements for all colors used. To confirm this finding, Chase ran some control tests in which a colorless spot was moved over either a colorless background or a colored background that was at least

25 per cent lighter than the moving spot. No pursuit movements occurred in either case. Chase accordingly concluded that these infants were responding to wave length and not to extraneous factors such as brightness differences.

Another interesting study was conducted by Staples (1932). Infants were presented with two discs of equal area, one colored and the other gray, both of equal brightness to the adult eye. The length of time spent in looking at the colored as opposed to the gray disc was taken as the measure of ability to see color. Staples found that by the age of 3 months, children spent almost twice as much time fixating on the colored disc as on the gray disc. Thus, according to Staples, these children perceived color.

In discussing the status of color-vision research in infants, Munn (1938) has taken what seems to be a reasonable view. He says: "If the brightness value of hues is alike for infant and adult, the results of these experiments indicate color differentiation in very young infants. If the brightness value of the various hues is not the same for infant and adult, most of the data on color vision in infants are equivocal."

Developmental Changes in Color Vision. So far, we have not been concerned with possible age changes in color vision. A number of such developmental studies have been performed. For convenience, they will be grouped under the headings of Color Tracing, Color Matching, Color Naming, and Color Preference.

Color Tracing. Synolds and Pronko (1949) studied the ability of children aged 3 to 8 years to discriminate colored digits on backgrounds of different hues and in a variety of combinations (Dvorine Color Perception Test). The subjects were presented with the color charts and asked to trace the digits with a paintbrush. None of the 3-year-olds was able to do the tracing, but children aged 4 to 8 showed gradual improvement in this task. Four-year-olds had no trouble with tracing red digits on blue backgrounds, or green or brown on orange; however, such combinations as blue digits on red backgrounds or green digits on yellow backgrounds were difficult for most of these age groups. A second and more extensive study by Pronko *et al.* (1949) in general confirmed these results.

Color Matching. Cook (1931) asked 110 children, aged 2 to 6 years, to match hues of red, green, yellow, and blue which varied in saturation and brightness. She found that the 2-year-olds were able to match the primary colors with an accuracy of 45 per cent. Ability in matching increased until, by the age of 6, 97 per cent accuracy was achieved. Children of all ages were able to match on a basis of hue better than on a basis of saturation or of brightness. All four of the primary hues were matched with equal ease. Both Tucker (1911) and Smith (1943), however, observed that school children found blue the most difficult color to match and yellow the easiest. Gilbert (1894), who made a more extensive study of 1,100 chil-

dren aged 6 to 17 years, demonstrated that matching colors by saturation improved up to the age of 17.

Color Naming. As might be expected, color naming improves with age. Since young children are greatly interested in color, they learn the names at an early age. Cook (1931) found that 2-year-olds could name the primary colors with an average accuracy of 25 per cent. By the age of 6, this accuracy had increased to 62 per cent. More recently, Synolds and Pronko (1949) noted a similar developmental trend in the naming of eight dark hues; an accuracy of 97 per cent was reached by the age of 7 years. No sex differences were observed. It is interesting that color naming is one of the items used in tests of intelligence for preschool children. One of the earlier tests, the 1922 Stanford-Binet, places the correct naming of the four primary colors at the 5-year age level.

It is doubtful whether improvement in color tracing, matching, and naming is due to any age increase in sensitivity to color. More probably, it is a result of a number of factors such as an increased understanding of instructions, refinement in the use of such terms as "equal" or "the same," increased ability to attend to stimuli, and finally a greater interest in colors.

Color Preferences. Experimental studies of color preferences at different age levels are numerous. Staples (1932) presented two discs, differently colored but of equal brightness, to infants and used as a measure of color preference the percentage of pointing and reaching responses made toward each of the colored discs. She found that, between the ages of 6 and 24 months, infants made from two to five times as many responses to red as to any other color. In descending order of preferences, colors preferred were red, yellow, blue, and green. After the age of 2, yellow steadily lost its popularity, while blue and green increased, so that in the later preschool years the order of preference became red, blue, green, and yellow. In grade school and in later adulthood, blue and green led the list. Other investigators, for example, Dashiell (1917) and Katz and Breed (1922), have obtained results in line with those of Staples. Katz and Breed made the interesting observation that children living in poorer districts showed a greater preference for red than children who came from better areas. This socioeconomic difference tended to disappear with advancing age.

It is well known that young children have a very strong preference for bright colors and avoid pastel shades. By adolescence, this tendency reverses, so that teen-agers avoid bright colors and prefer pastels. Doubtless this change is the result of training. In this connection it is also interesting to note that the more primitive peoples appear to prefer bright colors even in adulthood.

Visual Acuity. We have few data on the sharpness of vision of infants. This lack of data is probably due to the language barrier. Peckham (1933)

made an interesting modification of the Snellen Eye Test commonly used by doctors. This modification involved placing letters or figures at a fixed distance from the children and asking them to select cutouts resembling those at a distance. Peckham reports that by 28 months acuity is of the same order as that of adults. However, the small number of cases tested and the choice of a technique which is not particularly sensitive leaves his results open to question.

Discrimination of Pattern and Form. Children's ability to discriminate between patterns was investigated by Munn and Steining (1931) and by Gellermann (1933). The procedure used in both of these studies was to present the subjects with two boxes whose doors had different patterns on them. These door patterns were changed from one box to the other in random order. If a child selected the box whose door had a triangle on it, for example, he would find a cookie or a piece of chocolate; if he selected the box with another pattern, perhaps a circle, he found no reward. Munn and Steining were able to train infants of 15 months to discriminate between a triangle and a circle or between a cross and a square. Gellermann, who used a group of 2-year-olds, found that they were able to learn to select more complicated patterns such as a small cross in the center of a figure and to avoid choosing a similar box without the cross in the pattern. Chimpanzees were able to make similar discriminations. One of the interesting findings of Gellermann was that both children and chimpanzees who were unsuccessful in this discrimination for some time resorted to tracing the outline of the patterns with their fingers, and soon solved the problem in this manner. The additional kinesthetic stimulation derived from the tracing appeared to facilitate the learning of the patterns.

Three-dimensional Objects. Skeels (1933) tested the ability of children aged 15 to 46 months to discriminate the shape of three-dimensional objects. A number of differently shaped blocks—cubes, spheres, crosses, etc.—were placed before the children, who were required to learn that selecting a cube would produce a reward hidden under the block. All age groups were able to do this problem, and no improvement with age was noted. However, although the children of these ages could discriminate forms, they were unable to place them in the correct holes in a form board. Form boards are often used as parts of intelligence tests for young children. On the basis of his results, Skeels concluded that the ability to discriminate form develops earlier than the ability to see a relationship between two units having the same form.

Figure-Ground Discrimination. Well-known objects are frequently difficult to perceive if they are placed in new and different surroundings. Children may even find it difficult to recognize their own parents in a crowd. An experiment by Crudden (1941) relates to this problem. He taught primary-school children, 65 to 78 months old, to discriminate eight

pairs of figures. These readily recognized figures were then placed so as to form a part of a more complex pattern. Crudden reports that the children were able to "abstract" the familiar figures from the background if the background was not too complex. Children of superior intelligence did better than other children on this task. Girls showed better performance than boys.

Relative Strength of Form and Color. The question of whether form or color plays a more important role in perception of an object was studied
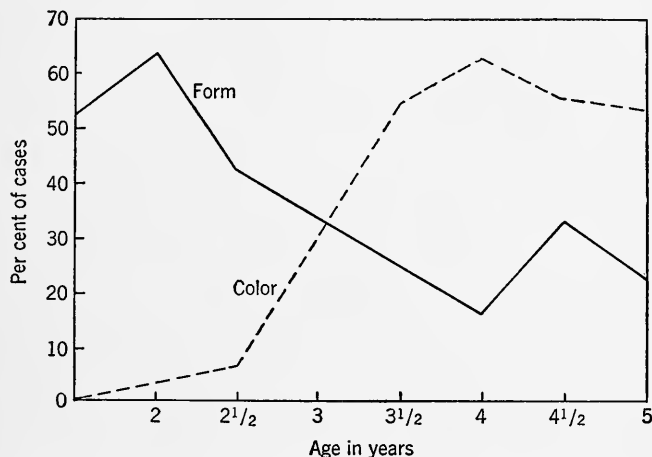
FIG. 54. Percentage of subjects making choices on the basis of form and color at various ages. (*From Brian, C. R., and Goodenough, F. L. The relative potency of color and form perception at various ages. J. exp. Psychol.,* 1929, **12,** 209. *By permission of the American Psychological Association.*)

by Brian and Goodenough (1929). Subjects ranged in age from under 2 years to adulthood. Two objects differing in both form and color were placed before the subjects. A third object, matching one of the first two in color and matching the second in form, was then introduced. For example, a subject might be shown a yellow ball and a red cube, while the third object might be a yellow cube. The subject was then asked, "Which of these two things is just like this one?" Thus, he had to select either the yellow ball (matched for color) or the red cube (matched for form). The results of the experiment are illustrated graphically in Fig. 54. It is evident that children under the age of 3 years show a marked tendency to match on a basis of form; from 3 to 6 years, color matching predominates. Finally, after the sixth year, form again becomes the preferred matching factor. Roughly 90 per cent of adults matched on a basis of form. These investigators offer an interesting explanation of their findings. They suggest that the early interest in form may be due to the major importance of form in the young child's first attempt to classify and to organize the objects

in his environment. The subsequent interest in color may relate to its importance in making finer discriminations among objects within the larger classes. Finally, a renewed interest in form after the age of 6 may result as the child learns that form classifications are more appropriate and effective than color classifications in adjusting to the environment.

Depth Perception. The status of depth perception in the newborn infant has received much attention, but most of it has been of a speculative rather than experimental nature. Many have wondered and argued whether it is innate or learned. In an attempt to determine whether or not the neonate perceives depth, cases have been cited of persons who were blind at birth and remained blind until adulthood when surgery successfully restored vision. Dennis (1934) has summarized some of these cases. Evidence indicates that persons whose sight has been restored through operation have difficulty in successfully reaching for objects placed before them. Carr (1935) states that such patients see the world as flat. He cites the case of a patient who leaned out of a window in an attempt to touch the ground far below him with a stick. Another patient exclaimed that the objects before him were "touching his eyes." Although these reports are interesting, they are anything but conclusive, since the disturbances are tied up with the general excitement of seeing for the first time. Frequently, too, such operations impair or destroy the mechanisms of accommodation which are so important in depth perception.

Undoubtedly depth perception involves both maturation and learning, for not only are adequate development of accommodation mechanisms and coordinated movement of the eyes necessary, but the child must also learn that great convergence of the eyes means that the object is nearer than when convergence is slight. He must also learn the various psychological cues to distance; for example, that the clearer the detail, the closer is the object, that larger objects are near, and other such cues as interposition, linear perspective, and differences in shading. Anyone who attempts to walk downstairs wearing a new pair of glasses for the first time will understand the experience of a child in this regard. If he does not wear glasses, he has only to watch a youngster moving from a polished floor surface to a rug: the exaggerated height to which the foot is raised to pass over this slight elevation offers mute evidence of the learning process.

Even before the age of 1 year, however, children have some rough estimate of distance. This is seen when they fail to reach for an object over 2 ft. away. Through playing with tops, riding tricycles, and other such experiences, they learn quickly. At first they learn to estimate distances with respect to their own bodies: Can they reach that far? Can they run that far? Can they climb that high, and so on. Later they begin to appraise space unrelated to themselves: How far apart are those trees? How far is it from here to daddy's office or to grandma's house?

Updegraff (1930) compared the relative accuracy of depth perception of children and adults. In one of her studies, 4-year-old children and adults were required to indicate the nearer of two lights. One light was kept at a fixed distance, while the other was moved nearer or farther away. She found that the children could discriminate distance at this age but discriminated less finely than adults. Similar findings were obtained in another study in which she requested children of 2½ to 4 years and adults to state whether a ball was dropped in front of or behind a partly opened screen. Only 5 children out of 19 were able to discriminate a difference as fine as 3.5 cm., although all 16 adult subjects did so without difficulty. Data thus indicate some improvement in depth perception with age. This may be related, however, to factors of attention, language, and understanding of directions and such quantitative words as "nearer" and farther," rather than to depth perception per se.

Perception of Illusions. It is generally believed that young children, lacking the critical attitudes of older children and adults, are particularly susceptible to illusions and that this susceptibility decreases with age. The few scattered reports which are available to date contradict any such broad generalization. Sander (1928), who devised the well-known Sander parallelogram figure in which the diagonals, although equal in length, are perceived as unequal, reports that this illusory effect is at a maximum in children and subsequently decreases with age. On the other hand, Cramausel (1927), who studied the Muller-Lyer illusion, observed scarcely any illusory effect in young children 4 to 7 years of age but noted increases thereafter. Both of these studies, however, suffer from the use of small samples as well as from the absence of statistical tests of significance.

The only extensive study is that of Hartmann and Triche (1933), who presented eight illusions drawn on cardboard to a group of 249 subjects from grades 1 to 6 and to college students. Each figure was presented to the subjects for a period of 10 sec. They were then requested to note on a sheet of paper either the letter "A" or the letter "B," corresponding to whichever line appeared longer or larger to them. No significant age differences were obtained for any of the figures, with the exception of the Muller-Lyer illusion, where adults showed a greater illusory effect than the younger groups. Perhaps greater differences might have been obtained if nursery or preschool children had been included in the sample.

Although there appears to be little age change in illusions of a paper-and-pencil nature, a study by Dresslar (1894) indicates that age differences occur in other kinds of illusion. Dresslar presented children with a series of metal objects of different sizes, but of the same weight and shape, and asked the children to arrange them in order of weight. He reported that over half of the children arranged the objects in the exact order of their size. No such illusion was present in early adolescents.

Nature of First Visual Experience. Before leaving this section on the early developmental changes in vision, let us look at a question which has puzzled investigators for many years: What is the nature of the visual world of the neonate or adult who can see for the first time? Most of us, perhaps, imagine that an otherwise normal adult whose vision has been restored can open his eyes to look at a familiar world made up of familiar objects. It seems strange to us that this should not be so. Long ago William James suggested that the neonate's world was a "big, booming, buzzing confusion." Although we lack experimental data on the newborn infant, we do have evidence on adults who can see for the first time, and we know now that James's suggestion was not far wrong.

Work of Von Senden. The scientific literature contains several reports of persons, blind from birth, who were able to see in later life as a result of successful cataract operations. Von Senden (1932) assembled reports of 65 such cases ranging in age from 3 to 46 years at the time when they regained their vision. His descriptions of the first sight of these patients are highly dramatic.

At first, all the patients were aware of visual stimulation but were unable to recognize everyday objects such as pencils, keys, coins, or fruit, even though these objects were familiar to them through tactual experience. Most patients could detect something different between such objects as a key and a pencil, often in terms of brightness; others could see no difference; not one was able to identify the object until he touched it. Friends remained unrecognized until they spoke. Patients continued to be guided by touch in moving about the room, and some closed their eyes to do so. In addition to the lack of ability to discriminate shapes and patterns, size perception was also absent. Some patients, for instance, were presented with two strips of cardboard, one 10 cm. long and the other 20 cm. They could see a difference but could not state which was the shorter, although they understood "shorter" in terms of touch. Perception of movement and of distance were also deficient. A movement of the hand was interpreted not as movement but as a change in illumination; a house a mile away was estimated to be a few feet distant.

Thus it seems that at first sight the world around us is amorphous, poorly structured, and confusing. However, it is not totally lacking in form, for patients can perceive a figure as distinct from its ground—a black blob on a white background, for example. An interesting feature of this poorly structured visual environment is the predominance of color, but the color "has no shape or size or locality; it is a passive reception of optical impressions."

Although patients are at first unable to identify objects and their characteristics, they learn the various visual factors with time, but at different

rates. Learning to name colors is relatively easy; learning to discriminate size, distance, and movement takes longer; most difficult of all is acquiring the ability to recognize forms or shapes—even such simple forms as squares or triangles may take many weeks of continuous training. Furthermore, ability to generalize comes much later, for even when a patient has learned to identify objects promptly, recognition is usually lost if the object is changed slightly or placed in a different setting. A patient who has learned to name a white triangle, for instance, may be unable to name it if its color is changed to blue or if it is taken off the table and held in the experimenter's hand. Von Senden reports that the *shortest* time in which a patient can approximate normal perception of several simple objects is a month; most patients require several months, and some need years before they are able to identify readily simple geometric figures or read letters or numbers. Before they achieve this, they pass through a long period in which they attend to parts of the figures (*e.g.*, counting corners) and infer identity from the elements of each object. Only when they have passed through this stage can they recognize objects at a glance.

Such data indicate that we must *learn* to see even the simplest patterns and that this learning process is slow indeed. The nature of this process has been well summarized by Hebb (1949), who states that "the course of perceptual learning in man is gradual, proceeding from a dominance of color through a period of separate attention to each part of a figure, to a gradually arrived at identification of the whole as a whole . . . . It is possible that the normal human infant goes through the same process and that we are able to see a square as such in a single glance only as a result of complex learning."

Animal Support: Riesen. Von Senden's observations might be questioned on various grounds were it not for supporting animal evidence which in most respects confirmed them. Several years ago, Riesen (1947) had two chimpanzees, Snark and Alfalfa, which he reared in darkness from birth to the age of 16 months. When Snark and Alfalfa were brought into the light for the first time, they exhibited a number of visual reflexes such as constriction of the pupil to light, turning of eyes and head in the direction of a light source in a dark room, and a startle reaction in response to a sudden change of illumination. All these reflexes clearly indicated sensitivity to light. Apart from these reflexes, however, the animals were for all practical purposes blind. They failed to blink when a blow was directed toward the face, and when an object was brought slowly toward them they showed no response until it actually touched the face, giving rise to a startled jump. Neither Snark nor Alfalfa responded to play objects or feeding bottles with which they were tactually and kinesthetically familiar, although they picked up such objects quickly if

they touched some part of the body. Another interesting observation was their strong desire to cling to the experimenter; if separated from him, however, they were unable to return and groped about blindly.

Considerable exposure to light and many repeated experiences with objects were necessary before Snark and Alfalfa could recognize objects. Alfalfa showed the first blink to a threatened blow after 5 days in the light but responded consistently only after 48 days. The first signs of visual recognition of the feeding bottle appeared at 11 days, and the first movements to apprehend it on the sixteenth day (normal chimpanzees can reach out before 12 months of age). The first reaching movements were very inaccurate, and several weeks passed before any degree of precision was exhibited. Snark's learning was somewhat slower. Various training procedures revealed that both animals were slow in learning avoidance responses such as fear of visual stimuli (certain patterns associated with shock). Normal animals will avoid a disc after being shocked by it once or twice; on the other hand, animals reared in darkness must be shocked about 15 times before they will show even the first signs of whimpering at the sight of the disc.

Considering the data of Von Senden and Riesen together, it is clear that learning plays an important role in identifying objects and their various characteristics. Presumably the neonate's visual world is not identical with the universe of the child or adult.

Later-age Changes in Visual Functions

Before looking at the changes that occur in visual functions in later years, let us briefly examine the structural changes. Extensive work on this topic has been carried out (see review of Friedenwald, 1952), but only the more important structures need concern us.

Some Structural Changes. All components of the eye undergo structural changes with age to some degree or another (Friedenwald, 1952). With advancing years, the cornea tends to lose some of its luster and transparency, and changes occur in the iris producing a gradual fading of the color of the eyes. One of the most important changes is a decrease in the size of the pupil. Table 7, based on the data of Birren *et al.* (1950*a*), shows this change in pupil size between the ages of 20 and 90 years. Measurements were taken under conditions of both light and darkness. Beginning around the age of 30, there is a considerable decrease in the size of the pupil. This experimental finding is of great importance, since it indicates that older individuals may do poorly on visual tasks as a result of reduction in the total amount of light entering the eye rather than as a result of any reduction in visual sensitivity. Sloan (1940) has shown that the effective light striking the retina is proportional to the size of the pupil. In view of the considerable decrease in pupil size shown by Birren

et al., consideration will have to be given to this factor in any study of age changes in visual functions in which illumination plays an important role.

Lens. Another structural change of behavioral significance is that which occurs in the lens of the eye. It has already been mentioned that changes in the curvature of the lens enable us to see clearly objects located at varying distances from the eye. These changes are dependent on the elasticity
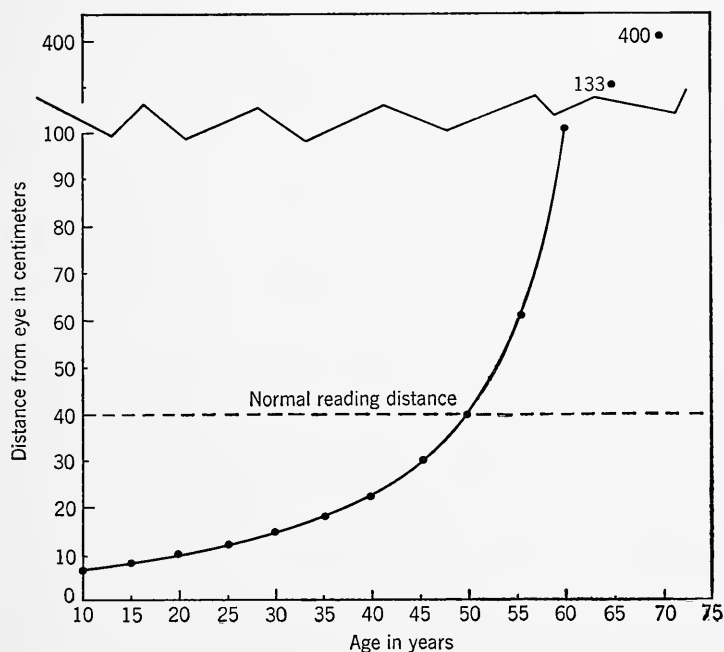
FIG. 55. Changes in the near point of vision with age. (*From Poffenberger, A. T. Principles of applied psychology. New York: Appleton-Century-Crofts, 1942. P. 54. By permission of the publishers.*)

of the lens. In young children, the lens is extremely elastic, so that objects may be seen clearly anywhere from several inches to great distances from the eye. With increasing age, however, this elasticity decreases, and with it the range of accommodation also diminishes. Figure 55 shows the changes in *near-point vision* from age 10 to age 70 (Poffenberger, 1942). The near point is the point closest to the eye at which an object may be seen clearly. With advancing age, this near point gradually recedes from 7 cm. at 10 years to 15 cm. at 30 years; by 60 years of age, an object must be 1 meter or a little over 3 ft. distant to be clearly seen. Beyond this age, the near point recedes still farther. Fortunately, however, this loss of power of accommodation can be corrected by glasses with appropriate convex lens.

Retinal Changes. Changes in the retina have also been observed. Friedenwald (1952) states that degenerative changes in the periphery of the retina appear quite regularly in nondiseased eyes during the fifth decade of life. These changes involve the disappearance of some of the retinal layers. Beyond middle age, degeneration encroaches more and more

TABLE 7. CHANGES IN SIZE OF THE PUPIL WITH AGE UNDER LIGHT AND DARK CONDITIONS*

Age	N	Size in light Mean diameter, mm.	Size in dark Mean diameter, mm.
20–29	32	5.11	7.42
30–39	20	4.64	6.72
40–49	25	4.09	5.91
50–59	32	3.77	5.89
60–69	42	3.48	4.78
70–79	36	3.52	5.10
80–89	34	3.42	4.87

* From Birren, J. E., Casperson, R. C., and Botwinick, J. Age changes in pupil size. *J. Geront.*, 1950, **5**, 217. Quoted by permission.

toward the central region. In cases of ocular disease, these changes may appear at an earlier age. Birren *et al.* (1950b), who studied the eyes of 109 male subjects aged 40 to 83, observed degenerative changes in both central and peripheral areas in even the youngest group. More than half of the subjects over 60 showed degenerative changes.

Changes in Electroretinogram. In view of these degenerative changes in the retina one might expect certain changes in the electroretinogram. Such was found to be the case. Karpe *et al.* (1950) recorded ERG's for 40 subjects over the age of 50, excluding all individuals whose eyes were found upon clinical examination to be unhealthy. Next they compared the ERG's of the experimental subjects with those of a control group of younger individuals, aged 17 to 50. A decline in the *B* wave appeared about the fiftieth year and became particularly noticeable after the age of 65. Apart from this declining *B* wave, no other change in the ERG was observed. Since the *B* wave is believed to represent neural activity in the optic nerve (Granit, 1947), it seems that from the age of 50 on there is a gradual decrease in the function of the optic nerve. Since no concomitant change occurred in the *A* wave, which, as we have previously stated, is believed to represent receptor activity, the indications are that no age changes in the rod-cone system occur with advancing age—at least no change large enough to be reflected in the ERG.

Sensitivity of Eye in the Dark. All of us have noted that when we pass from a lighted room to a dark one, for example, when we enter a darkened

theater from the well-illuminated lobby, we are unable to see anything for a brief interval but soon become used to the dark. Such orientation to the darkened theater results from an increase in light sensitivity with increasing time and is called *dark adaptation* (see Fig. 56). Numerous investigators have studied possible age changes in sensitivity of the dark-adapted eye. In general, these studies may be grouped according to the degree of change: (1) those showing no age changes (Philips, 1939); (2) those showing slight changes (Sloan, 1947); and (3) those showing considerable change with age (Ferree *et al.*, 1934; Robertson and Yudkin, 1944; Stevens, 1946; Birren *et al.*, 1948).

With the exception of the study by Birren *et al.*, all these investigations suffer because of the small number of cases used—especially of older subjects—and also because no account was taken of decreases in pupil size with advancing age. Birren and his collaborators used a sample of 130 subjects, ranging in age from 18 to 83 years; in this study the values were also corrected for diminishing pupil size. The subjects were left in the dark for half an hour. At the end of this time their dark-adaptation thresholds were determined by noting the intensity of light which they could just see. No significant changes were observed between the ages of 18 and 50; after 50, however, there was a slight decline which became more marked after the sixtieth year. Thus, beginning around the age of 50, people are able to see less well in the dark than in their youth. This decrease in sensitivity closely parallels the decrease in size of the B wave of the ERG and suggests that decreased neural activity of the optic nerve is at least partly responsible for diminishing sensitivity. Since correction was made for the decrease in pupil size in this study, it may be ruled out as a responsible factor.

Changes in Dark Adaptation throughout Life Span. Information concerning the sensitivity of the eye in young subjects is provided by Ferree *et al.* (1934) and by Hunt (1941). Ferree *et al.* found that children between the ages of 9 and 15 were less sensitive in the dark than postadolescents. Similarly, Hunt noted that children between 12 and 19 years were less sensitive than adult subjects. Thus, combining these data, we may conclude that sensitivity of the eye in the dark is poor in children, improves until late adolescence, remains fairly stationary up to middle age, and declines after the age of 50.

Rate of Dark Adaptation. So far, we have been concerned with the sensitivity of the eye after 30 min. of darkness. Figure 56 shows the dark-adaptation thresholds after various intervals of darkness up to 30 min. for various age groups (Birren and Shock, 1950). It can be readily seen that after all time intervals the older subjects have higher thresholds—that is, they are less sensitive to light. However, it is interesting that although there is a noticeable change in the level of adaptation, there is no age change in the *rate* at which adaptation to dark takes place.

Reasons for Decline. In an attempt to discover the reason for this decline in visual sensitivity with advancing age, Birren *et al.* (1950*b*) made an ophthalmoscopic examination of the eyes of all their subjects in conjunction with the sensitivity tests discussed above. They found significant differences in light thresholds between the older subjects with and without retinal degeneration. They noted, however, that the decreased sensitivity with age was not entirely due to degenerative changes, for the sensitivity of old subjects without retinal degeneration was still worse than that of younger subjects. Next, they determined the vitamin-A level of the blood. We should mention here that vitamin A is one of the breakdown products which result when light strikes the visual purple; it is also essential for regeneration of the visual purple in the dark. No changes in vitamin-A level occurred with age; neither was any relation between vitamin-A level and dark adaptation apparent. This confirms earlier findings of Haig and Patek (1942). Furthermore, daily administration of 100,000 units of vitamin A for a period of a month produced no improvement in the night vision of a group of 12 aged subjects. Thus changes in vitamin-A level can be eliminated as a factor in diminished light sensitivity.

Fig. 56. Dark-adaptation curves of different age groups. Note that while the level of dark adaptation increases with age the rate of adaptation remains the same. (*After Birren, J. E., and Shock, N. W. Age changes in the rate and level of visual dark adaptation. J. appl. Physiol.*, 1950, **2**, 409.)

Extent of the Visual Field. Indications are that there is a narrowing of the visual field with advancing years. Mann and Sharpley (1947) mapped the extent of the visual field in a group of 80 subjects between 10 and 70 years of age, using a perimeter. Subjects, tested in the dark, were required to fixate on a red spot in front of them. At the same time, a small luminous spot on the arm of the perimeter was moved outward in various meridians until the subject could no longer see it. Narrowing of the field of vision began during the third decade, and by the age of 60 it had been reduced by 10 degrees. During the next 10 years it narrowed further by another 13 degrees, but this value is open to question because it was based on only one subject in this age group.

Narrowing of the visual field has also been demonstrated under day-

light conditions—narrowing being somewhat less than when perimeter tests are given in the dark. Ferree *et al.* (1930) observed a narrowing of approximately 3 degrees between the ages of 30 and 60 years. The progressive narrowing of the visual field with increasing age can be accounted for largely by the degenerative changes beginning in the periphery of the retina and gradually working inward.

Flicker. Few visual phenomena have been as extensively studied as flicker, especially with regard to possible age changes. At some time or other, all of us have observed that intermittent flashes of light at a certain rate produce a flicker. If the rate of the flashes is increased, the flickering disappears or seems to blend into a steady light. Such phenomena form the basis of the neon signs used to attract attention to the local theater or restaurant, for example. The number of flashes or cycles necessary to produce a steady illumination is called the *critical flicker frequency*, or c.f.f.

Flicker in Children. Several studies on c.f.f. in children are available. Meili and Tobler (1931) studied children between 5 and 6 years of age; Hartmann (1934), ages 6 to 11; and Miller (1942), a wider age range from 6 to 19 years. No changes in c.f.f. with age were observed by any of these investigators. Furthermore, no significant differences between c.f.f. values of children in these age ranges and of adults have been reported. The neural mechanisms mediating c.f.f. evidently develop at a relatively early age.

Changes throughout Life Span. As far as later-age changes in c.f.f. are concerned, there is quite general agreement that c.f.f. decreases with age, but agreement is lacking on the amount of this decrease and on the time of its first appearance (Simonson *et al.*, 1941; Brozek and Keys, 1945; Misiak, 1947). Findings of these investigators are open to some doubt, however, because such small numbers of cases were used and because the age ranges included in the samples were narrow.

More recently, Misiak (1951) carried out a more extensive study of 319 subjects ranging in age from 7 to 89 years. His findings are illustrated in Fig. 57. Evidently there is a gradual decline in c.f.f. with age, the functional relationship being linear and negative. For the youngest age group, about 44 flashes per sec. produce fusion so that the light is seen as steady; for the oldest group, 36 flashes per sec. produce the same result. While a steady decline in c.f.f. appears, according to Fig. 57, only the decline beyond the age of 55 is significant when tested by statistical procedures. A great deal of overlap in scores for various age groups was evident in this study. The c.f.f. values at the age of 82 were sometimes as high as those at the age of 7; on the other hand, some c.f.f. values of children were as low as those of octogenarians. Furthermore, there was a marked increase in variability of scores with advancing age. This is in line with the results obtained on tests of other capacities. Since no corrections were made for

decrease in pupil size in this study, some of the decrease in c.f.f. may be due to this factor.

Sex Hormones and Flicker. Simonson *et al.* (1944) reported some dramatic improvements in the flicker vision of six subjects, aged 48 to 67, who were given testosterone orally for a period of time. The effects of such administration were tested by comparing these experimental subjects with controls who had been given placebos for the same length of time. Simonson *et al.* reported that all six experimental subjects showed significant increases in c.f.f. after the testosterone treatment. Between 3 weeks
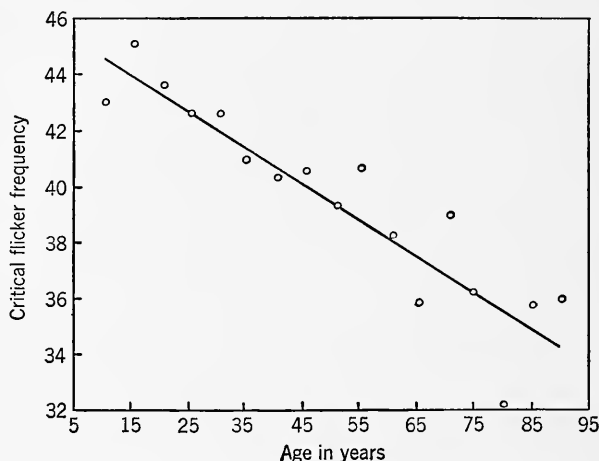
Fig. 57. Relationship between critical flicker frequency and age. (*From Misiak, H. The decrease of critical flicker frequency with age. Science,* 1951, **113**, 552. *By permission of the American Association for the Advancement of Science.*)

and 3 months was required for the increase to reach a maximum level. When the treatments were stopped, the c.f.f. decreased again, dropping to pretreatment level. Resumption of treatment again increased the c.f.f. Over-all increase for the six subjects averaged about 6 cycles. In view of the small number of cases, further research is needed before these findings can be definitely accepted.

Visual Acuity. Interest in age changes in visual acuity or sharpness of vision dates back to the time of Galton. In 1884, Galton made some 17 measurements which included visual acuity, using as subjects over 7,000 visitors to his first anthropometric laboratory at the health exhibition in London. These visitors were of a wide age range, and his data accordingly covered the span from 6 to 80 years. As a measure of visual acuity, he noted the distance in inches at which diamond type could be read. It was not until 1927, however, that any statistical analysis of Galton's data was made. Ruger and Stoessiger (1927) undertook this considerable task. Galton's results indicated that visual acuity is poor in young children,

increases rapidly until a maximum is reached around the age of 20, and declines slightly between 20 and 45 and more rapidly thereafter. Since Galton's time, at least 12 studies have been done on this topic. In general, all investigators have found the same type of function as Galton did with his cruder measurements (for example, Collins and Britten, 1924; Karpinos, 1944; and Chapanis, 1950).

Retinal Degeneration and Acuity. Birren and Bick (1948) carried out an important study on 107 subjects aged 40 to 83 years. They found that visual acuity decreased through this age range but, more important, they were able to show by means of ophthalmoscopic examinations that this decrease was correlated with the degree of retinal degeneration in both peripheral and macular areas. Laird (1945) claimed that marked improvement in visual acuity can be produced in older subjects with degenerative changes confined to the macula, by administration of various iodine compounds. He gave iodides to 115 such subjects, aged 52 to 87 years, and observed improvements in vision in 89 per cent of the cases. His findings are difficult to evaluate, however, since he reports only the results and does not mention his experimental procedures.

Color Vision. Although color vision in infants has been studied for many years, it is only in the last decade that any work has been done on color vision in the later years. First to raise the question regarding possible age changes in color vision were Tiffin and Kuhn (1942), who tested a total of 7,141 industrial workers for red-green color discrimination. Their results were astounding. They reported that 26 per cent of the workers between 20 and 25 years of age failed to pass the test. The number of failures increased with advancing age until 65 per cent of all workers over the age of 55 failed in red-green discrimination. In view of the tremendous practical and theoretical importance of these findings, the results have been subjected to close scrutiny and the findings severly criticized (Boice *et al.*, 1948; Chapanis, 1950). These and other critics have stated that (1) the color-vision test used was of questionable reliability and validity; (2) no data were given concerning the sample other than age range and a statement that the subjects were industrial workers; (3) no data were given concerning testing procedures. Moreover, the high failure rate (26 per cent) of the best age group is at variance with the results usually obtained with other color-vision tests. In view of these criticisms as well as others which have been made of this study, it is difficult for us to accept the findings of Tiffin and Kuhn.

Subsequent studies on age changes in color vision have not generally corroborated the findings of Tiffin and Kuhn. Boice *et al.* (1948) observed no age changes in color vision in a group of 215 faculty men, aged 20 to 59, at the University of Minnesota. Chapanis (1950), who studied a group of 574 subjects ranging in age from 7 to 77 years, found a slight positive

relationship between age and scores on five different tests of color vision, but when he excluded the poor color-vision scores of children under 15 years, he obtained no such relationship.

The literature suggests that perhaps, after 60 years of age, there may be some decrement. Boice *et al.* (1948) found that 20 per cent of a group of 40 men over the age of 60 were color-blind. Similarly, Kleemeier (1952) noted a decline in color vision in 128 males aged 65 to 85 years. Although Chapanis (1950) observed no decline after age 65, his sample in this age group consisted of only 9 cases and can therefore be discounted. Kleemeier reported a high correlation ($r = .56$) between color vision and visual acuity
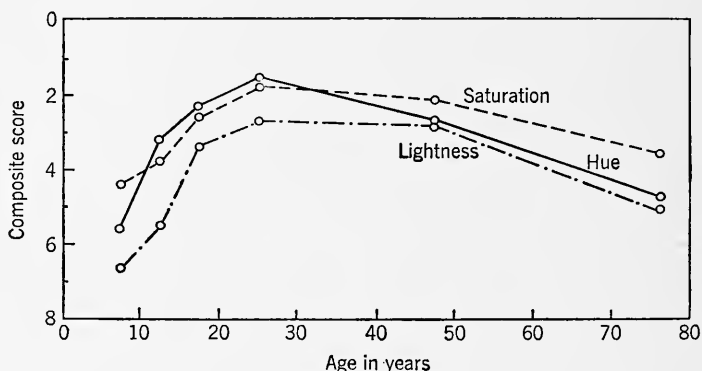
FIG. 58. Relationship between age and ability to match hue, saturation, and brightness. (*From Smith, H. C.   Age differences in color discrimination. J. gen. Psychol.*, 1943, **29**, 204. *By permission of the Journal Press.*)

in his subjects. He suggests that a decline in color vision beyond the sixth decade is due primarily to a deficiency in visual acuity rather than to any defect in color vision per se.

Color-matching Ability and Age. We have seen that the ability to match colors improves from 2 to 17 years. Smith (1943) has provided some data for the later years. A group of 199 subjects, ranging from 5 to 87 years, were required to match colors on a basis of hue, saturation, and brightness. Figure 58 shows the results for the three color matchings. The ability apparently increases rapidly from age 5 through adolescence, reaching a maximum around the age of 25. No significant changes occur from early adulthood until the age of 65, at which time the ability begins to drop off. Generally speaking, this relationship with age is the same for all three matchings. In interpreting his findings, Smith states that the decline in matching ability in the later years may best be accounted for by changes in attitudes toward the tests rather than by physiological changes which occur at that time.

Depth Perception. Tiffin (1946) has contributed the only available data on age changes in depth perception in later years. He studied 8,412 indus-

trial workers between the ages of 20 and 70 years. According to Tiffin, the ability to discriminate distances increases until the age of 35, remains constant until 50, and then falls off rapidly. Unfortunately, Tiffin again neglected to provide any details of his experimental procedures or the nature of his sample.

Age, Illumination, and Performance. One investigation has recently been made of the relationship between age, illumination, and performance. Weston (1948), who studied subjects ranging in age from 20 to 50 years, presented them with sheets of paper on which were a large number of small rings with gaps in them—the position of the gap varying from ring to ring. The subjects were asked to locate all the rings with gaps in a particular position and to cancel these by a pencil stroke. This task was performed under various levels of illumination. This test is especially interesting because of its similarity to such practical jobs as proofreading, reading numerals, and other common tasks requiring close inspection. It was found that with advancing age performance fell off significantly, declining more sharply under conditions of dim light than under high illumination. A change from the lowest to the highest illumination improved the performance of the youngest group by only 18 per cent, while performance of the oldest group increased fourfold. The practical applications of this finding are obvious.

Perception of Incomplete Figures. Age changes in the accuracy with which elementary- and high-school students are able to perceive figures were studied by Street (1931). He showed 13 incomplete pictures to 754 grade-school and high-school pupils. Each picture was held before the group for 3 min. The students were then required to identify it. No age differences were observed in the number of correct identifications. It is quite likely, however, that if a more precise measure, such as the time required for each identification, had been used as an index, some age differences might have appeared.

In studies of older groups, age differences have been found. Verville and Cameron (1946) presented 10 incomplete pictures of such common objects as ships and aircraft to a more varied group of 100 students, aged 16 to 23 years, and to 30 professional people, aged 35 to 56 years. The pictures were flashed on a screen and the time required to identify each figure recorded. The younger subjects were able to identify the objects much more quickly than the older subjects.

HEARING

Phylogenesis

Present evidence indicates that no organisms below certain of the arthropods possess auditory organs. In the lower organisms, the entire

body is sensitive to vibration, but no specific auditory receptors exist. In-sects have certain structures called *chordotonal* and *tympanal organs*, which may be considered a type of auditory structure. These structures resonate sympathetically in the presence of vibrations such as sound waves. In grasshoppers, for example, they are located on the abdomen; in crickets, on the forelegs. Experiments have demonstrated that in certain insects these organs respond to frequencies ranging from 500 to 45,000 cycles—the upper limit being much above the limit of human sensitivity. Although these arthropod organs respond to various frequencies, they do not have any genetic relationship to the vertebrate ear.

Fishes. Fishes have a primitive inner ear consisting of a saclike organ made of two parts, the *utricle* and the *saccule*, from which arise two or three semicircular canals. All vertebrates above fishes have three semi-circular canals. The entire structure is known as the *vestibular organ*. Fishes have no middle ear, and the inner ear performs chiefly an equilib-rium function. Within the utricle and saccule are a number of small crys-tallike objects which move around when the organism moves, thus stimu-lating the many hair cells with which they are lined. This differential stimulation of the hair cells informs the organism of the position of its body in space. Structures containing such crystallike particles can be found in invertebrates as low as the coelenterates, in which they perform a similar function. While the utricle and saccule are position-sense organs, the semicircular fluid-filled canals inform the organism of changes in mo-tion. Vestibular organs of fishes are about as highly developed as in any higher animal and change very little during the course of evolution. How-ever, fishes have no organ comparable to the cochlea of man. They do possess a slight protuberance known as the *lagena* (see Fig. 59*A*). The cochlea evolves from this at later stages of phylogenesis. There is some evidence to indicate that the lagena performs an auditory function, effective for only low frequencies, however.

Amphibians. In the amphibians, the lagena has enlarged slightly as shown in Fig. 59*B*, but the main change is in the introduction of a middle ear. As in man, this middle ear communicates with the pharynx through the Eustachian tube. Using the frog as an example, we see the appearance of a bony rod (*columella*) with a stirruplike structure, the *stapes*, at its end. This rodlike structure transmits sound vibrations from the eardrum to the inner ear. Although the lagena is larger in amphibians than in fishes, auditory sensitivity remains poor and is limited to low frequencies of around 50 to 100 cycles.

Reptiles. In reptiles, the eardrum is drawn partly into the head, pre-senting the first appearance of the *external auditory meatus* that is so prominent in human beings. In alligators, for example, a thin skin fold sug-gests the external ear of higher forms. The middle ear of reptiles is char-

acterized by the addition of a spur to the columella and also by the introduction of the oval window to which the stapes is attached. It is in the inner ear that the greatest development is seen, however, with the assumption of most of the features of the mammalian inner ear. The lagena becomes considerably extended and slightly curved. It contains, for the first time, a *basilar membrane.* Along with this development one might expect increased auditory sensitivity. This expectation is not altogether borne out, however. Some reptiles are fairly sensitive to high frequencies of 4,000 cycles or so, but others are sensitive only to low frequencies. It is interesting that not all reptiles have a middle ear. Snakes, for instance, have no such structure and consequently are insensitive to airborne vibrations of any kind. Thus, it is highly probable that rattlesnakes cannot hear their own rattle.

Birds. The auditory equipment of birds shows some advance over that of reptiles. The external auditory meatus becomes more pronounced and slightly curved to protect the eardrum from possible injury. Some birds—the owl, for example—have movable external ear flaps. The middle ear is

FIG. 59. Evolution of the inner ear in vertebrates. *A,* fish; *B,* amphibian; *C,* bird; *D,* mammal. *Sc,* semicircular canal; *Co,* cochlea; *U, S, L,* utricle, saccule, lagena. (*After Von Frisch. From F. A. Moss (Ed.), Comparative psychology. New York: Prentice-Hall,* 1934. *P.* 176. *By permission of the publishers.*)

reduced in size, but few other changes accompany it. Perhaps the greatest development is in the lagena, which enlarges and becomes partly coiled (see Fig. 59C). Moreover, the basilar membrane enlarges and, for the first time, supports the *organ of Corti,* the auditory receptor cells. Development of the organ of Corti in birds has led to the belief that the first true cochlea really occurs in these organisms. Research on the auditory sensitivity of birds indicates that their sensitivity is of about the same order as that of mammals. They are able to discriminate pitch and intensity, and their sound localization is very accurate.

Mammals. In mammals, an external movable flap, the external ear, develops, and the eardrum is more deeply embedded in the head. The middle ear becomes characterized by the presence of three bones, or ossicles, called the *malleus,* the *stapes,* and the *incus,* which replace the former long columella. What was the enlarged lagena in birds now be-

comes quite coiled and is henceforth referred to as the cochlea. This is shown in Fig. 59D. The number of turns, or spirals, of the cochlea varies in different mammals and appears to be independent of their size. This varies from $\frac{1}{4}$ turn in the duck-billed platypus, for example, to about 4 turns in the pig. Man's cochlea has $2\frac{3}{4}$ turns. Many mammals are sensitive to frequencies well beyond the range of man (20,000 cycles). The upper limit for dogs approximates 35,000 cycles; for cats, 50,000 cycles; for bats, 98,000. It is interesting that the bat makes use of ultrasonic frequencies for locating objects in the dark.

Human Auditory System

The human auditory apparatus consists of the external ear, the middle ear, the inner ear, and the auditory nerve pathways. Only a part of the inner ear is auditory in function; the remainder performs an equilibratory role. The gross anatomical features of the auditory structures are shown in Fig. 60.
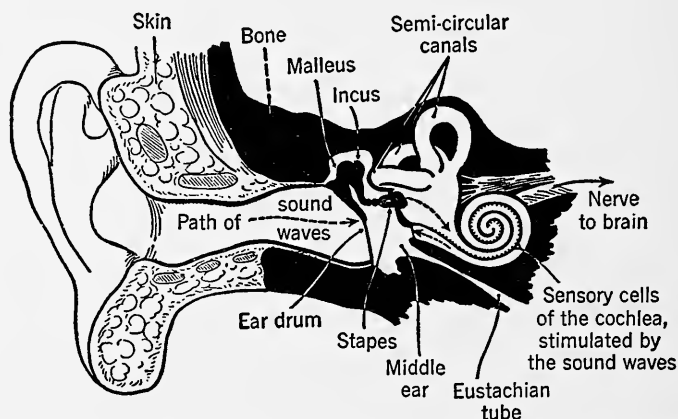
FIG. 60. A schematic drawing of the ear. The dotted arrows show the course of the sound waves from the external ear to the inner ear. (*Modified from H. Davis* (*Ed.*), *Hearing and deafness. New York: Murray Hill Books, Inc., 1947. P.* 110.)

External Ear. The external ear consists of two parts: the pinna and the external auditory meatus. The *pinna* is a cartilage structure attached to the side of the head and is popularly referred to as the "ear." In animals, it serves a useful function in collecting sound waves and directing them into the eardrum. Man's inability to move the pinna, even though muscles are present, makes it a vestigial organ with no important function as far as hearing is concerned. Auditory waves striking the pinna are conducted along an S-shaped passageway, the *external auditory meatus*, at the end of which is the eardrum, or *tympanic membrane*.

Middle Ear. The middle ear is a small, irregular bone cavity containing three small bones which form a chain across the cavity and connect the eardrum with the posterior wall of the middle ear. These bones are the malleus, the stapes, and the incus, mentioned earlier. In the innermost region of the middle ear are two openings, the *oval window* and the *round window*. These are closed by membranes which communicate with the inner ear. The upper of these openings, the oval window, is connected to the stapes. Vibrations of the eardrum are transmitted through the malleus, then to the incus, and finally through the stapes, which either pushes in or pulls out the membrane covering the oval window. These vibrations are thus transmitted to one of the fluid-filled canals of the cochlea (scala vestibuli). Below the oval window is the round window, which is at the end of the fluid-filled system and bulges in or out depending on the vibration of the stapes—oval window connection. In addition to these two openings, there is a larger one, the *Eustachian tube*, which connects the middle-ear cavity with the pharynx. This opening serves as a means of equalizing the air pressure on both sides of the eardrum.

Inner Ear. The inner ear consists of the cochlea, utricle, saccule, and semicircular canals. Of these, the cochlea is the primary auditory structure; the other three organs are nonauditory in function. The cochlea, a spiral structure of $2\frac{3}{4}$ turns, resembles a snail's shell. The upper diagram of Fig. 61 illustrates it as it would look if it were uncoiled and shows more clearly the division into three parallel parts, or canals. These canals are all filled with a fluid. The upper canal is called the *scala vestibuli*, or, more commonly, the vestibular canal. It is closed off at its base by the oval window with the stapes attachment described above. The lower canal is called the *scala tympani*, or tympanic canal, and is blocked off at its base by the round window. The scala vestibuli and the scala tympani communicate with each other at the apex of the cochlea, so that they are actually a single canal doubled back upon itself. Separating these vestibular and tympanic canals is a triangular passage called the *scala media*, or cochlear canal. This contains the actual auditory receptors.

Inner Structure of Cochlea. The middle diagram of Fig. 61 gives a cross-sectional view of the cochlea. It can be seen that the three canals are formed as a result of the presence of two membranes. Separating the scala vestibuli from the scala media is a thin, cellular membrane called the *membrane of Reissner*. The other membrane, separating the scala media from the scala tympani, is a stout, tendonous membrane called the *basilar membrane*. This basilar membrane is very important, because it bears the actual auditory receptors which turn inward into the scala media. The lower diagram of Fig. 61 shows an enlarged view of the basilar membrane and its related structures. Lying on the basilar membrane are a great

many long narrow cells arranged in parallel fashion similar to the stakes of a palisade. From their flat upper surfaces a number of fine hairlike processes arise. These structures are the hair cells, the true end organs of hearing. They are arranged in four rows along the length of the basilar mem-
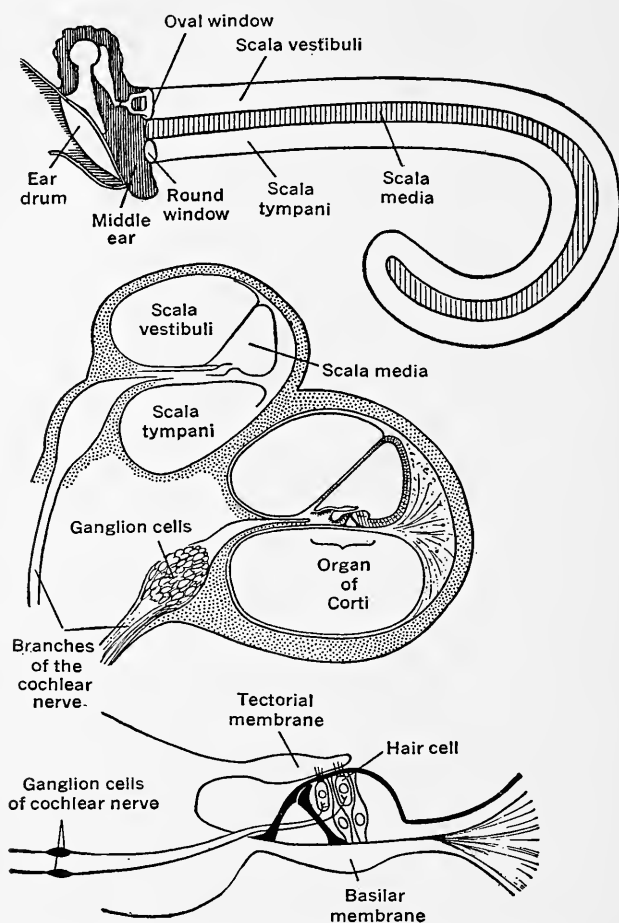
FIG. 61. Various schema of the inner ear. The upper drawing shows the cochlea as if it were uncoiled. The middle drawing represents a view of the cochlea as it would look in cross section. The lower drawing is of the receptive region, the organ of Corti. (*From Gardner, E. Fundamentals of neurology. Philadelphia: Saunders, 1952. By permission of the publishers.*)

brane. In addition to the hair cells, the basilar membrane also contains some supporting cells scattered among the hair cells. Collectively, these cells are all referred to as the organ of Corti. Above the hair cells is a very delicate membrane, the *tectorial membrane*, into which hair-cell bristles project.

Auditory Nerve Pathways. At the base of the hair cells are many fine nerve fibers whose axons make up the auditory, or VIIIth, nerve, which leaves the cochlea and proceeds to areas 41 and 42 of the cerebral cortex through a rather complicated system of pathways.

Physiology of Hearing. Having sketched the anatomical aspects of auditory development, let us next see how sound waves striking the pinna eventually result in stimulation of the hair cells of the organ of Corti to give rise to neural impulses. Air waves which strike the pinna are deflected into the external auditory meatus, striking against the tympanic membrane and setting it vibrating. These vibrations are then carried across the middle ear by the three bones to the oval window, attached to the last of this bone chain, the stapes. The in-and-out movements of the stapes set up corresponding movements in the fluid of the vestibular canal. When the stapes pushes against the oval window, pressure waves are set up which pass through the membrane of Reissner and the scala media to the basilar membrane, pressing it downward and thus stretching the hair cells attached to the tectorial membrane. On the other hand, when the stapes moves outward, the tension on the hair cells is released. This stretching and releasing action on the hair cells excites the sensory endings, innervating the hair cells, and nerve impulses are transmitted up the auditory pathways to areas 41 and 42 in the temporal lobe of the cortex.

Vestibular Structures. As was mentioned earlier, the inner ear also contains a structure known as the *vestibular organ*. This is not concerned with hearing but rather with equilibrium. The vestibular organ consists of three semicircular canals and two saclike pockets, the utricle and the saccule, which are both filled with fluid (see Fig. 59). These are the structures which enable us to maintain our balance when we are walking, running, cycling, or otherwise moving about. Furthermore, they inform us of the direction in which the body is moving—right, left, backward or forward, ascending or descending. The semicircular canals are hollow membranous passages filled with fluid. They lie at right angles to each other, so that one of the three canals parallels each of the three dimensions of space. At the base of each canal is an enlargement known as the *ampulla*, containing elongated hair cells known as *cristae*. These cristae are innervated by a branch of the vestibular nerve. During the course of rotary movements of the head, the fluid in the canals is set in motion, bending the hair cells and thus exciting the associated sensory nerves which leads to awareness of movement. Associated with this motion of the fluid are certain compensatory eye movements known as *nystagmus*. Effects such as dizziness and staggering gait and certain autonomic effects such as pallor can result from stimulation of these canals by rapid rotary movements.

While the semicircular canals and the cristae are stimulated by changes

in rotary movements of the head—more specifically, when such motion involves acceleration or deceleration—the utricle and the saccule are static receptors. This means that they respond to changes in position of the head and not to movements of the head. The utricle and saccule have groups of hair cells, known as *maculae*, which are attached to the walls of the canals. These hair cells are overlaid with gelatinous masses called otolithic membranes, containing a great number of crystallike structures known as *otoliths*. As the position of the head changes, these otoliths are displaced and stimulate the underlying hair cells to give rise to impulses transmitted to the brain through the vestibular nerve. Thus, through the receptors of the utricle and the saccule, we are informed about the position of our head in space.

Early Developmental Changes in Hearing

The various parts of the human ear have different embryological origins, but these need not concern us here. We do know that by the third month after fertilization, the three parts of the ear—external, middle, and inner—can be recognized. During the succeeding months they undergo various changes in shape and structure, attaining complete differentiation late in the fetal period. Hamilton *et al.* (1945) observed such essential structures as the basilar membrane and the organ of Corti in well-defined form in a 250-mm. fetus, that is, one about 8 lunar months after fertilization. Although structural differentiation of the ear is complete before birth, the middle ear remains filled with a gelatinous fluid until some hours after birth. Such activities of the newborn infant as breathing and crying help to drain this fluid from the ear.

Prenatal Hearing. The sense of hearing differs from the sense of sight in that adequate stimuli are present even while the fetus is within the uterus. Such sounds as the fetal and maternal heartbeats, rumblings of the mother's intestinal tract, and sounds produced by the rubbing of the mother's clothing against her body could all serve as adequate stimuli for hearing. Although the auditory mechanisms are sufficiently developed for functioning prior to birth, various investigators have maintained that the fetus cannot hear such sounds and that it is deaf because of the presence of fluid within the ear. While we do not know whether the fetus can be activated by sounds originating in the mother's body, we do have some data which suggest that it can respond to or "hear" sounds produced outside the body if they are sufficiently loud.

Early Studies. One of the earliest experiments devised to determine whether or not the fetus can respond to external environmental sounds was done by Peiper (1925). Peiper used a "loud and shrill" automobile horn to furnish the stimulus. Recording tambours were placed on the abdomen of the pregnant mother in such a way that any generalized fetal

movements could be recorded through the body wall of the mother. Great care was taken to prepare the mother so that she herself would not respond to the sound of the horn but would remain in a relaxed state. Mothers who could not achieve this relaxation throughout were excluded from the experiment. Peiper found that in over one-third of the cases definite fetal responses were recorded following the blast of the automobile horn.

Another observation on fetal responses to sound has now become almost a classic. Forbes and Forbes (1927) reported that a month before her baby was due to arrive a mother was lying in a bathtub full of water. One of her small children was playing near the bathtub and accidently struck the side of the tub with a glass jar, thus producing a loud sharp sound. Immediately the mother felt a sudden jump of the fetus—a movement quite different from the usual fetal movements which she had experienced previously. Some days later, and under similar conditions, an experimenter struck the side of the tub below the water line with a metal object, observing a "single quick rise of the anterior abdominal wall" a fraction of a second after the sound. The mother experienced the same sensation as before. She herself was not startled, since she had been told what to expect. Further experiments indicated that the mother herself experienced no skin vibrations set up by the impact on the tub. The conclusion seemed to be that the fetus was responding to noise rather than to tactual vibration.

More Recent Studies. Several other reports suggest that loud sounds can elicit fetal movements (Ray, 1932, for example). In recent years, investigators have been able to use more sensitive indexes of reaction, such as changes in fetal heartbeat, and as stimuli have used tones rather than noises (Sontag and Richards, 1938; Bernard and Sontag, 1947). These investigators used as subjects mothers who were in the last 2 months of pregnancy. Fetal heart rates were recorded by means of a microphone strapped to the mother's abdomen over a point at which the fetal heartbeat was the strongest. Various tones ranging in frequency from 20 to 6,000 cycles and of various intensities were tried. These were generated by an oscillator and transmitted to a speaker located some inches above the abdomen but directly over the head region of the fetus. The particular location of the loud-speaker served to concentrate the tones on a desired region of the abdomen and also to decrease the intensity of sound reaching the mother's ear, thus minimizing the effect on her. Records were made of fetal heart rate in several subjects before and after stimulation with various tones. It was noted that tone stimuli were followed by a great increase in heart rate. Various controls were made. These tests indicated that the increases in heart rate were not due to activity of the mother but represented spontaneous fetal activity prompted by the sound stimuli.

Thus, these data indicate that the late fetus is capable of reacting to a wide range of tones. Whether the heart reaction was brought about by activation of the cochlear mechanisms is another question. Bernard and Sontag (1947) state that these changes in heart rate may be due to vibratory action on body structures other than the ear. However, their data strongly suggest that true "fetal hearing" of tones is present before birth.

Hearing after Birth. Interest in the problem of whether the infant can hear immediately after birth dates back over many decades. The earliest experimental studies in this area were done in the nineteenth century. Early investigators used such stimuli as bells, whistles, rattles, horns, and tuning forks; auditory sensitivity was gauged by such reactions as movements of body parts, screaming, awakening from sleep, changes in respiration, and changes in pulsations of the large fontanel of the infant's head. Some of the early investigators asserted that neonates are totally deaf; others obtained some reaction to sound. Most of these data, however, indicate that the newborn infant will respond to sound providing the stimuli are sharp, sudden, and loud (see review of early literature in Pratt *et al.*, 1930). This relative insensitivity of the neonate for all sounds except the very loud ones is generally attributed to the presence of the *amniotic fluid* in the middle ear. It gradually drains out during the first week.

Age Changes. Various studies show that sensitivity to sound increases with age. Peterson and Rainey (1910) observed the reaction of 48 infants to sounds of rattles, tearing paper, falling of a hammer head, etc. They noted considerable individual differences. Eleven of the subjects reacted to the sound of a rattle within 1 hr. after birth; 16 responded within 2 hr.; 23 responded within 3 hr.

One of the more extensive and more carefully executed studies was carried out by Pratt *et al.* (1930). The subjects were 59 infants ranging from 0 to 21 postnatal days. The sounds used to provoke response were produced by a coffee can, a snapper, an electric bell, a Chinese wooden bell, and a 350-cycle tuning fork. The infants were placed in a *stabilimeter*—a platform inside an enclosed cabinet and resting on ball bearings so that any movement of the infant can be recorded on a moving strip of paper. In addition to recording the total amount of activity, these investigators were able to observe and record through a small opening in the cabinet various specific movements of their subjects such as eye and head movements and facial reactions. On the basis of stabilimeter records, they found a gradual increase in the total amount of activity from birth onward. Forty-seven per cent of this activity was in response to the can, 21 per cent to the electric bell, 16 per cent to the snapper, 9 per cent to the Chinese bell, and 7 per cent to the tuning fork. This reaction order does not entirely follow the relative loudness of the sound stimuli—for ex-

ample, the Chinese bell was second in loudness (after the can), yet it elicited approximately the same amount of reaction (9 per cent) as the tuning fork (7 per cent), which was least loud as gauged by the adult ear.

It has been found (Hetzer and Tudor-Hart, 1927) that reactions to noises are greater and occur more frequently than do reactions to the human voice, even when conversation is loud. It is not until the fourth week that responses to the human voice become more frequent.

Perception of Pitch. So far, we have been concerned chiefly with reaction to various kinds of noises. What data are available on response to tones of different frequencies? Perhaps the best study is that of Stubbs (1934), who controlled intensity, duration, and pitch of his stimuli. To record responses he used the stabilimeter, and for sound source he used an audiometer, through which he could produce various frequencies and at the same time control intensity. Frequencies of 128, 256, 1,024, and 4,096 cycles were each presented for a duration of 10 sec. He recorded respiratory changes as well as general stabilimeter activity. It was found that these four pitches all produced some reaction in the newborn infant. However, he was unable to see any differential effects of the different pitches on either stabilimeter or respiratory records. Accordingly, his study indicates that newborn infants can perceive pitch but give no evidence of discriminating differences in pitch. Stubbs further noted that, if a stimulus was of constant duration but increasing loudness, the infant exhibited more bodily movements, closed the eyelids oftener, and showed greater respiratory changes. Increasing the duration of the stimulation (1 to 15 sec.) produced similar increases in responses. However, if stimulation was prolonged to several minutes, activity was generally inhibited and movements decreased to a lower level than with no stimulation at all (Pratt *et al.*, 1930, and others).

The use of the conditioned-response technique was reported by Kasatkin and Levikova (1935). They studied three infants who, at the start of the experiment, were less than a month old. These investigators were particularly interested in testing the infants' ability to discriminate tones and attempted to condition sucking responses to one tone and not to another. The first differential sucking responses were noted at the age of $2\frac{1}{2}$ months. The two tones had to be at least 2 octaves apart before conditioning was effective; by the age of 4 months, this difference could be reduced to 1 octave. Finer tonal discrimination could not be obtained.

Auditory Acuity. Experimental data suggest that sharpness of hearing increases between the ages of 3 and 13 years (Williams, 1932; Weinberg and Fischgold, 1932). Children were required to repeat numbers heard over a telephone-receiver recording. The loudness of the spoken numbers could be decreased until a point was reached at which the child was not able to repeat the numbers. This low point was taken as the threshold for

each child. According to the results of this study, auditory acuity increases until the age of 10 years and then levels off. Whether this increase is a true increase in sensitivity or whether it is due to such psychological factors as increasing attentiveness and better ability to follow instructions is difficult to say.

Localization of Sound. A popular experiment in most psychology laboratory courses is the demonstration that it is difficult to localize accurately sounds which are placed in the mid-line, either directly in front of, behind, above, or below the subject. Sounds placed away from the mid-line can be localized quite accurately, however. This ability to localize the source of sound depends on the use of a number of cues whose significance must be learned over the years. Although auditory localization has been extensively studied in adults, investigations of the ontogenesis of such ability are practically nonexistent. A few early investigators made some casual observations of when infants begin to orient their heads toward the source of sound. Their estimates range from the eleventh to the twentieth week, however. Gesell (1925) states that no infant under the age of 20 weeks can turn his head in the direction of sound when the stimulus is placed 6 in. to the side of the ear. Age changes in accuracy of auditory localization are totally lacking.

Later-age Changes in Auditory Functions

Whereas the literature on children's hearing abilities is scanty, studies on later childhood and adolescence are nonexistent. There are a few scattered reports of age changes in adulthood and old age. Nowhere is the material sufficient to provide any continuous picture. Although psychological studies in this area are rare, the literature on anatomical changes associated with age is quite extensive (see review of Guild, 1942). For our purposes, however, it is sufficient to say that age changes in the structure of the outer, middle, and inner ear do occur.

Changes in Inner Ear. The inner ear is of some concern to us, since the auditory receptors are located there. After surveying the literature, Guild states: "There is general agreement that the most common lesion of the inner ear in elderly people is simply atrophy, of greater or lesser degree and extent, of the nerve or of the nerve and end organ in the basal turn of the cochlea." This involvement of the basal turn which mediates high-tone sensitivity will become important in our discussion on deafness in the elderly. Another finding of behavioral significance is that obtained by Rasmussen (1940), who performed a histological examination on the cochlear portion of the VIIIth nerve of 21 subjects, aged 2 to 26 years, and 19 subjects, aged 44 to 60 years. He found that the older group possessed an average of 2,200 fewer cochlear fibers than the younger group (32,500 and 30,300).

Incidence of Deafness in Population. It has been known for many centuries that people become more and more deaf with advancing age. Extensive data on the incidence of deafness in the various age groups were obtained by Beasley (1941) during the national health survey of 1935–1936 carried out in the United States. Over 2½ million people in various parts of the country were sampled by house-to-house canvass, and 13 audiometric clinics were set up. Beasley found that the incidence of deafness rose gradually from 2.95 per 1,000 cases for males aged 5 to 14 to 175.08 at age 75 or over. For females, the incidence rose from 2.26 per 1,000 to 135.95, in the same age groups. Except in the age group 25 to 34, deafness was more common among males than among females. Furthermore, Beasley reported that the incidence of hearing impairment is higher in the lower than in the higher socioeconomic groups. It is important to note that 70 per cent of this information was obtained from the family by a canvasser and thus excludes many cases of partial deafness which may be detected only through audiometric tests. The above figures are therefore conservative, since they represent only quite hard-of-hearing cases. Montgomery (1940), who analyzed the World's Fair hearing tests, also observed an increasing incidence of hearing impairment with advancing age and corroborates Beasley's finding that males show greater incidence of deafness than females.

High-tone Deafness. Although increase in incidence of deafness with age has been common knowledge for centuries, it has only quite recently been discovered that this deafness involves primarily the higher-tone frequencies. Zwaardemaker, around 1891, using Galton's whistle, noted a decrease in the upper limit of hearing in elderly subjects. The first to demonstrate this on any large scale and by the use of the audiometer was Bunch (1929), who extended this study later (Bunch, 1931). A total of 821 subjects ranging in age from the third to the sixth decade were tested. Figure 62 graphically illustrates his findings. The hearing loss is measured in units of intensity called *decibels*. As the figure indicates, hearing loss is slight or nonexistent up to the age of 60 years for all tones of frequencies up to 512 cycles. Kelly (1939) showed that this lack of any significant loss for frequencies up to 512 cycles extends to ages beyond 60 (to age 86, in his study). Returning to Fig. 62, we note that the 1,024- and the 2,048-cycle tones show scarcely any loss for the two younger groups, aged 30 and 40 years, but that the curves for age groups 50 and 60 have dropped considerably. For tones higher than 2,048 cycles, each successive age group shows greater and greater loss. Only a few elderly subjects could hear tones higher than 8,192 cycles even when these tones were increased to high intensities. Thus we see that the higher the tone is above 512 cycles the greater is the impairment with advancing age. Guild (1942) reports that when very high frequencies are used the loss in sensitivity can

be detected even in early adulthood. He determined the intensity of a tone of 16,384 cycles which a group of young medical students (average age, 23) could just hear, and compared these threshold values with the values obtained from children aged 10 to 15. He found that greater intensity was required for the young adults to hear the tone than was required for the children. This progressive loss of hearing of high tones with age is known as *presbycusis*.
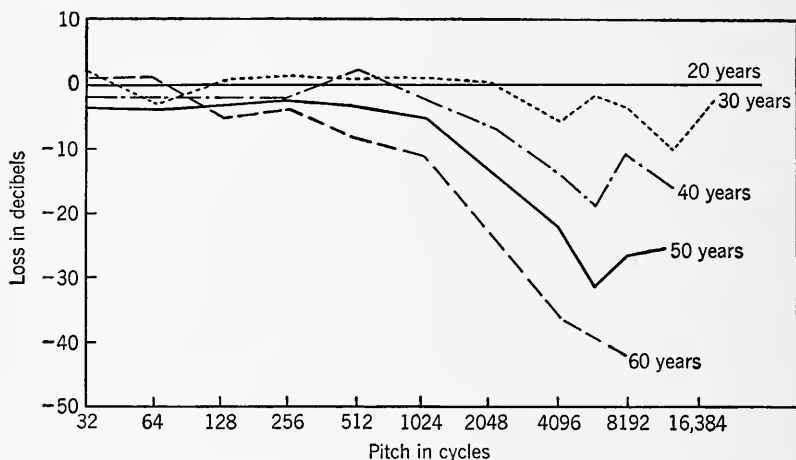
Fig. 62. Changes in sensitivity of hearing with age. Note the lack of hearing loss for pitches up to 512 cycles for all age groups. (*After Bunch. From Poffenberger, A. T. Principles of applied psychology. New York: Appleton-Century-Crofts, 1942. P. 55. By permission of the publishers.*)

Studies carried out subsequent to Bunch's are in line with his findings, with the possible exception that the losses at the various frequencies are not quite so large as Bunch reported (Ciocco, 1932; Kelley, 1939; Montgomery, 1940; Leisti, 1949).

Sex Differences. One of the interesting findings made by Bunch (Bunch and Raiford, 1931) was that definite sex differences were present in auditory sensitivity. Sex difference was absent up to 2,048 cycles, but from this value upward the females of all age groups were able to hear high tones much better than the males, *i.e.*, they showed less loss of hearing with advancing years. Subsequent studies confirm these sex differences (Ciocco, 1932; Montgomery, 1940; Leisti, 1949). The sex difference amounts to about 7 decibels.

Hearing by Bone Conduction. The discussion so far has dealt only with hearing by air conduction of vibrations into the ear. Another way in which we can hear is through transmission of the vibrations to the inner ear via the bones of the skull. Fowler and Fowler (1936) studied the changes in hearing by bone conduction, using as subjects 614 persons, aged 10 to 80 years. Their procedure was to measure the energy necessary

to vibrate a bone-conduction receiver so that it could just be heard when placed against the mastoid bone directly behind the ear. In general, they obtained the same sort of decrement function that Bunch and others found for air conduction. However, the hearing was quite good up to 1,024 cycles for all age groups but declined thereafter. In another study, Ciocco (1935) placed a tuning fork of 512 cycles on the mastoid bone of 907 subjects, aged 19 to over 70. He used as an index the length of time they could hear the tone. He, too, reported that the incidence of persons with shortened bone-conduction time increased with advancing age.

Mechanisms Responsible for High-tone Deafness. We have already mentioned that perhaps the most common structural change in the ears of the elderly is the atrophy of structures in the base of the cochlea. Various animal experiments indicate that the auditory receptors in this region of the cochlea mediate high-tone sensitivity (see Morgan, 1943). Perhaps the best human study is one by Crowe *et al.* (1934), who attempted to correlate hearing loss in the aged with degenerative changes in the cochlea. Serial sections were made of the ears of 79 patients who during their last illnesses had been given audiometric tests. The investigators found a relationship between the gradual hearing loss for higher tones and partial atrophy of the nerves innervating the organ of Corti of the basal turn. Furthermore, in the ears of persons who had shown a very marked impairment for high tones, they found not only atrophy of the nerves serving the organ of Corti but also degenerative changes in the organ of Corti of the basal turn itself. Guild (1942) states that this gross type of structural change is limited almost entirely to males and suggests that this may account for the sex differences in hearing impairment, according to which males show greater loss for high tones than do females. Exceptions were found in this, as in most studies. Crowe *et al.* reported that in roughly one-quarter of the cases in which high-tone impairment occurred there was no evidence of structural changes of any kind in either the middle or the inner ear. They suggest that perhaps atrophic changes may have occurred in some of the higher pathways and higher centers of the auditory system. The findings of Rasmussen (1940) that there is a decrease in the total number of auditory fibers with advancing age suggest that such a decrease may extend throughout the various levels of the auditory system.

Role of Nutritional Factors. There are reports that nutritional deficiencies may bring about high-tone deafness not only in elderly people but also in children. Selfridge (1939) reports on seven cases, 8 to 60 years, in which high-tone deafness was traced to poor diet low in vitamin B. He found that administration of various components of the B-complex group such as *thiamin* and *nicotinic acid* restored hearing in all cases. Nash (1949) states that normal but long-continued doses of vitamin B can at times

arrest or retard the development of high-tone deafness. He does not, however, give any quantitative results. In view of the practical importance of these results, more research is obviously needed.

Perception of Music and Speech. Kelley (1939) has provided some valuable data on the effect of high-tone deafness in elderly subjects on the perception of music and speech. A violin string was set into motion mechanically and the sound piped in a soundproof room. Each subject was requested to compare two tones, one of which was the natural violin tone

TABLE 8. PERCENTAGE OF SPEECH SOUNDS RECOGNIZED BY SUBJECTS OF NORMAL HEARING AND WITH HIGH-TONE DEAFNESS*

Sounds	Decibels	Normal ears	Presbycusic ears
Vowels..............	40	99	92
	30	99	90
	20	99	79
	10	94	49
Consonants..........	40	98	75
	30	97	63
	20	89	45
	10	65	21

* From Kelley, N. H. A study in presbycusis. Auditory loss with increasing age, and its effect on the perception of music and speech. *Arch. Otolaryng.*, 1939, **29**, 512. By permission of the author and the American Medical Association.

complete with all of its high-frequency components and the other the same tone with various high frequencies filtered off. Each subject was required to judge whether a difference in quality was present; if the reply was positive, the variable tone was altered until no difference in quality was detected. Kelley found that filtering off all frequencies over 4,000 cycles did not affect the experienced quality of the violin tone in subjects over 60 years of age who had presbycusis. Such elimination markedly altered the tonal quality for subjects with normal hearing. This finding suggests that the tonal quality of musical pieces is not so rich for elderly subjects as for the young. The old may also have some difficulty in perceiving qualitative differences among musical instruments.

In the next phase of this experiment, lists of monosyllabic words were transmitted over an amplifying system, and the subjects were required to identify the vowels and consonants. Recognition tests were given at various levels of intensity, ranging from 40 to 10 decibels above the average normal threshold of hearing. Table 8 presents the results. According to these figures, subjects with presbycusis, or high-tone deafness, were not severely handicapped in recognition of vowels at any intensity except the

lowest (10 decibels above threshold), where they could recognize only roughly half of the vowels that normal subjects were able to comprehend. In the recognition of consonants, however, the presbycusics were inferior at all levels of intensity. This is to be expected, since most of the consonants contain high-frequency components. Since the recognition of consonants is important for understanding speech, we may expect that elderly people will have difficulty in understanding what people at some distance are saying. For example, they will find it difficult to follow conversation directed to them from across the room, at gatherings, etc., and will also have trouble in understanding conversation in noisy environments or in identifying people by their voices.

Vestibular Functions. The vestibular apparatus, consisting of the semicircular canals, utricle, and saccule, assumes a definitive structure and appearance by the second month after fertilization, but just when function begins is a debatable question. Carmichael (1946), in a review article on vestibular functions, cites various studies in which various postural changes and righting reflexes have been observed in late fetuses in response to changes in position of the body in space. In the neonate, these reactions become more pronounced. For example, in neonates, the sudden movement of the head to one side may elicit a "fencing" posture of the limbs or a movement of the trunk. Whether these reactions are of vestibular origin, it is difficult to say, however, since physiologists have known for many years that these responses may be called forth by either vestibular activity or kinesthetic activity—*e.g.*, receptors in the neck—or a combination of both. Before we can state conclusively that these various reactions are attributable to the functions of vestibular structures, we will have to eliminate the role of kinesthetic factors by surgery. So far, this has not been done. The only clear evidence available on the early functioning of vestibular structures consists of the several studies in which nystagmus has been reported in neonates subjected to body rotation (Carmichael, 1946).

Age Changes. Literature on age changes in vestibular functions is negligible. One possible reason for this lies in the crudeness of available techniques. As far as structural changes in the vestibular apparatus are concerned, Guild (1942) states that "histologically there is no typical difference in the appearance of the vestibular structure in ears from old and from young individuals." Rasmussen (1940), however, studied 37 vestibular nerves of a young group (2 to 26 years of age) and compared the results with those of an older sample (44 to 60 years of age). He observed that there were roughly 1,000 fewer vestibular fibers in the older subjects (18,900 vs. 18,000). This finding may possibly be correlated with some behavioral changes reported by Noble (1946). A group of 369 subjects, ranging in age from less than 20 to more than 40 years, were tested in a

chair which was rotated rapidly through an angle of 90 degrees. The swinging was continued for periods up to 30 min. Incidences of vomiting were recorded for various age groups. The incidence for all age groups below age 40 was roughly 55 per cent; for those over 40, incidence rose to 74 per cent.

All of us have observed that young children enjoy activities involving considerable body rotation—for example, carrousels or spinning on a piano stool. Russo and Dallenbach (1939) supply some pertinent data. Children aged 10 to 16 were blindfolded and placed in a chair on a rotating platform. After a period of rotation, the motion was stopped abruptly and the behavior of the children noted. Questions were also asked about this experience. All experiences were classified as pleasant, neutral, or unpleasant. It was found that 52 per cent of the 10-year-olds considered the experience pleasant, while 48 per cent considered it unpleasant. With increasing age, the percentage of "pleasants" decreased, while an increasing number tended to vote for the neutral category. The unpleasant category remained fairly constant throughout the age range tested.

SENSORY DEVELOPMENT. II. CHEMICAL AND CUTANEOUS SENSES

In addition to vision and hearing, we are endowed with a number of other senses. First, we have taste (gustation) and smell (olfaction), the so-called chemical senses. Secondly, we have the skin sense (cutaneous sensitivity), which may be further subdivided into pressure, pain, cold, and warm sensitivities. Finally, we have the kinesthetic, or "muscle," sense which informs us of the position and movement of our limbs or other body parts. Very little is known about these three classes—much less than is known about either vision or hearing. This is partly because they are not of as great importance in our daily adjustments. Let us follow the pattern of the last chapter, however, and look at the phylogenetic and ontogenetic aspects of these lesser senses.

TASTE

Phylogenetic Development. In single-celled organisms, the entire body responds either positively, neutrally, or negatively to various chemical stimuli. From this general type of sensitivity, evolution proceeds in two directions toward (1) differentiation of an olfactory epithelium and (2) development of taste buds. The general chemical sensitivity is not altogether lost, however, but persists in many of the higher forms including man in the *common chemical* sense, found chiefly in exposed moist surfaces such as the mouth and throat. The first indications of specialization appear in the annelids, in which flask-shaped structures with protruding hairs constitute primitive taste buds. These early taste buds are very similar to those of vertebrates, as Fig. 63 illustrates. There is little difference in the structure of taste buds in either annelids, the lower vertebrates, or man.

Although few evolutionary changes in taste-bud structure occur, their distribution varies considerably. In annelids they are scattered over the entire body, although more concentrated in the head region. They are functional and quite sensitive to some substances such as quinine. Long

ago Charles Darwin demonstrated that even these lowly animals could discriminate between red and green cabbage leaves or between cabbage leaves and celery purely on a basis of taste. Ascending the scale, we find that certain of the mollusks have taste buds restricted to the mouth area. These react to a variety of stimuli—meat juices, weak acids, quinine, etc. (see Prosser, 1950). In summary, it may be said that the invertebrates have taste receptors which are fairly similar to those of the highest vertebrate forms, both in structure and in distribution.

Vertebrates. In some of the lowest vertebrates such as the fishes, taste buds are distributed around the mouth; in others, they are also scattered
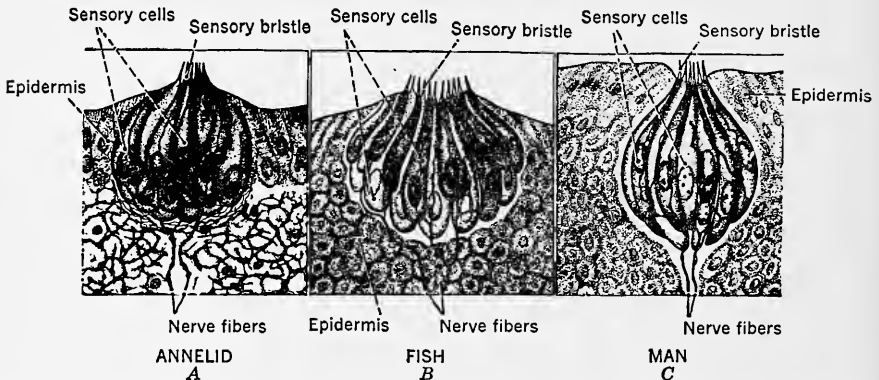
FIG. 63. Diagrams of taste buds in annelids, fishes, and man, showing their fundamental similarity. (*After Kahn. From Neal, H. V., and Rand, H. W. Comparative anatomy. Philadelphia: Blakiston, 1939. P. 578. By permission of the publishers.*)

along the sides of the body. Research has shown that fishes are sensitive to a number of chemical substances such as acids and salts and that they make practical use of this ability in their choice of food. With the assumption of land life, taste buds become restricted to the tongue and roof of the mouth. In amphibians, they are important in feeding; in most reptiles, however, they are poorly developed and play a very minor role. Ascending the scale to mammals, we find taste buds further restricted to the tongue and the back part of the mouth. Such evidence as is now available indicates that the taste sense is well developed and that even the lowest mammals show preferences analogous to those of man (Prosser, 1950).

Human Taste Organs. The mucous lining of the human tongue is covered with a large number of elevations known as *papillae*, which give the tongue its characteristic rough appearance. Buried in these papillae are the bulblike organs which we know as taste buds. Although they are most common on the top of the tongue, some may be found in the throat and larynx. Figure 63C illustrates the structure of a typical human taste bud.

As may be seen, it is made up of a number of sensory cells—the actual taste receptors—at whose base is an extensive network of nerve fibers. Their embedded location means that stimuli must be in liquid form in order to seep through the outer structure to reach the receptors.

Types of Papillae. Figure 64 shows that the top of the tongue contains several kinds of papillae. The largest of these, numbering 7 to 10, are the *circumvallate papillae*, which are arranged in V formation at the back of
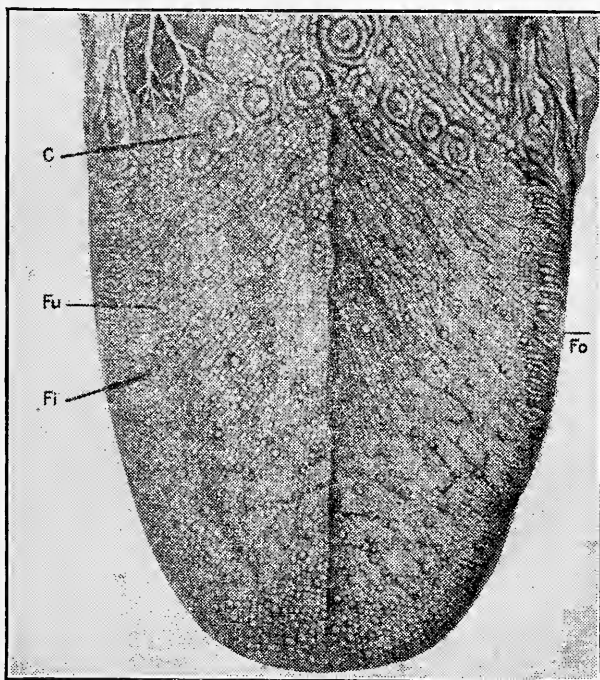
FIG. 64. The tongue, showing various kinds of papillae. The different types of papillae are *C*, circumvallate; *Fu*, fungiform; *Fi*, filiform; *Fo*, folliform. (*After Wenzel. From Freeman, G. L. Physiological psychology. New York: Van Nostrand, 1948. P.* **77.** *By permission of the publishers.*)

the tongue. Smaller but more numerous are the mushroomlike *fungiform papillae*, most common in the tip and along the sides of the tongue. There are other kinds of papillae, but they contain no taste buds. The taste buds are innervated by three different cranial nerves; the facial nerve serving those in the anterior two-thirds of the tongue, the glossopharyngeal nerve serving the posterior one-third, and the vagus, which innervates the few buds located in the throat and larynx. From the tongue these three nerves proceed through the medulla to the thalamus and finally terminate at the base of the postcentral gyrus of the cerebral cortex.

Developmental Changes in Taste

Taste buds make their appearance during the third fetal month. According to Parker (1922), they are very extensively distributed, during the early fetal period, not only in the tongue but also in the roof of the mouth, the back of the mouth, and parts of the esophagus. From the late fetal period onward, however, there is a gradual recession from the nontongue areas, and during early childhood they are concentrated around its tip with only a few remaining in the back of the mouth. Subsequently,

TABLE 9. AVERAGE NUMBERS OF TASTE BUDS CHARACTERISTIC OF CERTAIN AGE
GROUPS BETWEEN BIRTH AND 85 YEARS*

Age	Number of subjects	Number of papillae studied	Average number of taste buds per papilla
0–11 months.......	15	32	241
1–3 years..........	20	40	242
4–20 years.........	9	28	252
30–45 years........	18	47	200
50–70 years........	19	55	214
74–85 years........	13	46	88

* Based on data of Arey, L. B., Tremain, M. J., and Monzingo, F. L. The numerical and topographical relations of taste buds to human circumvallate papillae throughout the life span. *Anat. Rec.*, 1935, **64**, 18.

the number of taste buds in the front area diminishes, and by late adulthood few remain in the anterior two-thirds of the tongue. Those located in the posterior third and in the larynx persist. Thus we note a gradual shift in location from infancy to senescence, with the concentration moving slowly backward from the tip of the tongue to the region of the circumvallate papillae (Arey *et al.*, 1935). Unfortunately, there are no data to show whether or not maximum taste sensitivity shifts in similar fashion.

Changes in Number of Taste Buds. So far, we have been concerned only with age changes in the distribution of taste buds. Arey *et al.* (1935) have also provided some excellent information regarding age changes in the number of buds in one local area of the tongue. These investigators made a histological examination of the circumvallate papillae of subjects ranging in age from birth to 85 years, counting the number of buds in each papilla. The results of this study are recorded in Table 9. The number of taste buds per circumvallate papilla—about 250—remains fairly constant from birth to maturity, with some quantitative decrease beginning in the 30's. Until the age of 70, however, the decrement is small, but after this

age there is a considerable and rapid drop to 88 buds per papilla by the eighty-fifth year. In line with studies of other functions, Arey *et al.* observed an increasing variability with advancing age. Younger subjects showed a fairly constant number, while older subjects evidenced great individual differences in the number of buds per structure.

Early Developmental Changes in Taste. Investigators have long speculated whether or not taste sensitivity is present at a prenatal stage and whether the amniotic fluid which surrounds the fetus may, perhaps, act as a taste stimulator. This is doubtful, for the chemical composition of the fluid remains quite constant as pregnancy advances. With the possible exception of this fluid, no other taste stimuli are present in utero. A few scattered reports on premature infants indicate that some of them occasionally discriminate between sweet and salty, sour and bitter stimuli, if facial expressions are accepted as criteria. Perhaps the safest conclusion is that the mechanisms of taste are well developed during the fetal period but that it is only after birth that the receptors can be adequately stimulated (Carmichael, 1946).

Taste in Neonates. Literature on taste sensitivity in neonates is quite extensive (see review of Pratt, 1946). One of the most comprehensive early studies was carried out by Peterson and Rainey (1910), who observed the reactions of 1,000 newborn infants to various taste stimuli. They noted that during the first week of postnatal life, 800 of these infants made some kind of response to sweet, sour, salty, and bitter stimuli, while the remaining 200 showed reactions during the following week. Peterson and Rainey described the response to sweet and salty substances as being positive, indicated by contented sucking, and the reactions to sour and bitter as negative, shown by various discomfort reactions. Unfortunately, no objective measurements were made, and the findings are therefore subject to questioning.

A better-controlled study was made by Pratt *et al.* (1930), who used, in addition to the four taste primaries, distilled water as a control. The taste stimuli were all kept at room temperature and inserted into the mouth by an applicator dipped in one solution. Records were made of the general activity of the infants by means of a stabilimeter and also of such specific responses as head and facial movements. The investigators found that 85 per cent of the presentations of taste stimuli evoked activity changes in the infants. Presentation of distilled water, interestingly, evoked many sucking reactions, grimaces, and general activity responses. When Pratt *et al.* subtracted the percentage of responses to water from the percentage of responses to taste stimuli, little evidence of any taste sensitivity was found. Salt elicited responses 2 per cent of the time; sugar, 4 per cent; bitter, 9 per cent; and acid, 10 per cent. On the basis of these data, the investigators concluded that taste is not well developed at birth. As the infants

grew older, however, there was a rapid increase in the number of positive responses to sugar and negative responses to bitter and acid. An interesting observation made in this study was that infants do not respond to taste solutions in the same way adults do. For example, a concentration of quinine which was bitter to the adult experimenters elicited only a weak reaction from the infants, while a solution of citric acid which tasted weak to adults produced a strong infant response.

Although Pratt *et al.* claimed that taste was poorly developed at birth, Jensen (1932), who used a more sensitive technique, contradicted Pratt's findings. Jensen built a special feeding bottle pneumatically attached to a recording pen in such a way as to make possible a permanent chart record of sucking movements. By this means he was able to record differential sucking reactions to milk vs. salt solutions, acidic milk vs. salt, and milk vs. salt and sugar. Perhaps his most dramatic finding was that differential reactions could be made to two salt solutions varying in concentration by only 0.025 per cent.

Later Developmental Changes in Taste. The studies discussed so far have been almost exclusively concerned with whether newborn infants can or cannot taste various solutions. Unfortunately, investigators have shown little concern over possible age changes in later childhood, and consequently our knowledge of taste development during the early period of life is a total blank. A similar lack of interest in later-age changes is also apparent.

The only study reported to date was carried out by Richter and Campbell (1940) on 174 subjects broken down into three age groups: 7 to 10 years, 19 to 50 years, and 52 to 85 years. These subjects were blindfolded and presented with two glasses, one containing distilled water and the other a sugar solution of low concentration. They were required to taste the two liquids by sipping from the glasses. The concentration of the sugar solution was then gradually increased until the subject reported a sweet taste. This value was called the sugar-taste threshold. It was found that children first recognized a sweet taste at an average concentration of 0.68 per cent, while adults were able to do so at 0.41 per cent, and the elderly subjects at 1.23 per cent. It appears, therefore, that adults aged 19 to 50 are more sensitive to sweet solutions than either children or older persons. The very poor sensitivity to sweet taste in the oldest group was attributed to the greater atrophy of the taste buds. This is just what we would expect, since we know that the tip of the tongue is the most sensitive area for sweet and also that with increasing age the taste buds here are the first to atrophy. It would be interesting to repeat this experiment using in addition a bitter solution, since bitter is best experienced toward the back of the tongue in the region of the circumvallate papillae whose taste buds are last to disappear. Some impairment might be expected in the light of the

data of Arey *et al.* (1935), which indicated that buds of the circumvallate papillae decrease in number.

Age and Taste Preferences. All of us have observed that our taste preferences tend to change over the years. Laird and Breen (1939) submitted some data relevant to this observation. They used pineapple juice as a stimulus, developing it in 5 degrees of sweetness ranging from sweet to tart along equally perceptible intervals. A group of 160 subjects, aged 12 to 68 years, were asked to indicate which of a pair of taste stimuli they preferred. Each taste stimulus was judged in comparison with every other taste. The resultant preference curve was similar for the 12- to 20-year-olds and the 20- to 40-year-olds, both showing mostly sweet preferences and few tart choices. The older group, aged 50 to 68, showed a decrease in sweet preferences and an increase in tart choices, however. These investigators attributed the shift in preferences to atrophic changes in taste buds. As has already been noted, the taste buds of the anterior tip of the tongue, which are most sensitive to sweet, tend to disappear first, and so the diminishing choice of sweet may be at least partly due to structural changes with advancing age. Undoubtedly, psychological factors are also involved.

In a further study, Laird (1939) changed his groupings but used the same subjects and the same stimuli. This time he broke the sample down into smokers and nonsmokers. He found that this variable had no effect on taste sensitivity for either male or female of any age group except females aged 50 to 68. The elderly female smokers showed much greater preference for tart tastes than did the elderly nonsmokers. For some unknown reason, the elderly males showed similar preferences whether they smoked or not. Laird concluded that "the proper birthday gift for a smoking grandmother is not a box of candy but a jar of pickles."

SMELL

Phylogenetic Aspects. Prior to the development of any smell or olfactory mechanisms, the entire organism is sensitive to directly applied chemical stimuli. This seems to be the case with both protozoa and coelenterates. In the flatworm, however, ciliated pits in the front end of the animal are believed to perform olfactory functions, since some of these organisms can locate food placed at a considerable distance. These pits contain hair cells, connected to the "brain" by nerves. As was mentioned earlier, it is not until the annelids are reached that there is any differentiation of the chemical senses into taste buds and paired ciliated "olfactory organs." Whether the paired structures really perform any olfactory function is not certain, but there are indications that they may do so. In some land mollusks such as snails, for example, smell is very well developed.

This is well illustrated by the fact that snails were used as gas detectors during World War I. Snails withdraw into their shells in the presence of poison gas of such low concentration as to be imperceptible to humans. Arthropods—insects and crustaceans—also have keen olfactory senses. In these organisms the olfactory organs are hairs or bristles located especially in the front appendages.

Vertebrates. Although invertebrates have a number of different structures believed to be olfactory in nature, it has not been demonstrated that vertebrate olfactory organs evolve from any of them. In the *cyclostomes*, primitive vertebrates lower than fishes, a single nostril gives rise to two olfactory nerves, indicating that the original structures were paired. The nasal structure of fishes is characterized by two blind nasal sacs lined with olfactory epithelium, innervated by the olfactory nerves. As the fish swims about, water enters the anterior opening of the nasal sac and flows back through the posterior opening, in transit stimulating receptors at the bottom of the nasal sac. The next important advance occurs in amphibians, in which the nasal passages open internally into the roof of the mouth, thus associating the functions of breathing and smelling. The upper part of the passages contain olfactory receptors, while the lower part serves as a respiratory passage. This structural arrangement, with only minor changes, characterizes all higher vertebrates including man.

Accompanying changes in peripheral olfactory organs are changes in the amount of the brain given over to smell. In the primitive vertebrates, the front half of the brain is devoted exclusively to smell; in fishes, about a third of the entire brain. Ascending the scale, the smell brain, or *rhinencephalon*, becomes more and more reduced in size until, in the higher mammals and in man, it is restricted to a small region in the undersurface of the brain (see Fig. 11).

The many olfactory-discrimination studies show that olfactory sensitivity is present in fishes, amphibians, and mammals. In reptiles and birds, except in certain marine birds and carrion feeders, smell is poorly developed. In vertebrates such as the dog and deer, however, smell is extremely acute, and a well-developed "smell" brain is found in these animals. Although man retains only a rudimentary olfactory sense, he is highly sensitive to certain chemicals such as mercaptan, which may be detected in concentrations as low as 1 part in 30 billion parts of air (see discussion of Fields, 1942).

Human Olfactory Organs. Figure 65 is a cross section of the left nasal cavity of man. It is evident that this cavity is incompletely divided into four compartments, one above the other, by three bony ridges. The top compartment, or alcove, forms the site of the olfactory epithelium in which are embedded the smell receptors. This epithelium contains olfactory nerve fibers and is also innervated by the *trigeminal nerve*, which mediates the

sense of touch. Interestingly, it is the stimulation of this nerve rather than the olfactory which is responsible for the coolness and irritation elicited by sniffing such substances as menthol and ammonia. It is often difficult to dissociate the touch from the smell component in experimental work.
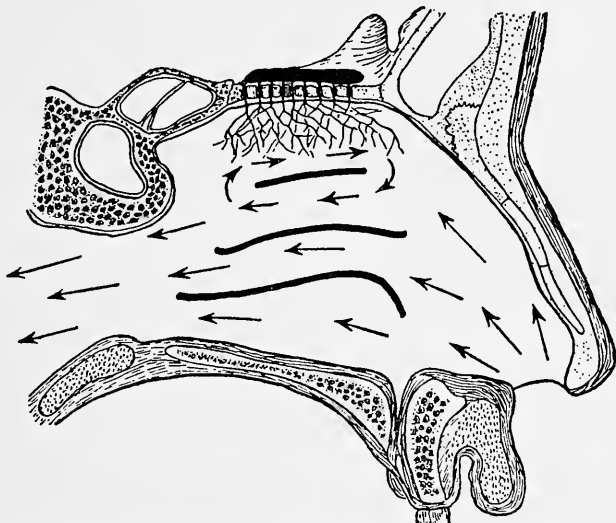
Fig. 65. Diagram of left nasal cavity. The three dark lines represent the region of the three bony ridges (conchae) dividing the cavity into four compartments. Arrows indicate the direction of air flow. The olfactory bulb is shown with nerve fibers extending into upper part of nasal cavity via openings in the bone. (*From Kimber, D. C., Gray, C. E., and Stackpole, C. E.   Textbook of anatomy and physiology. New York: Macmillan, 1942. P. 643. By permission of the publishers.*)

Developmental Changes in Smell

The olfactory organ is one of the first to appear during the prenatal stage. The earliest indications may be seen in a 4-mm. embryo (4 weeks). By the seventh week, olfactory nerves appear, growing centrally in the direction of the cerebral hemispheres (Hamilton *et al.*, 1945). In view of this early development, it is likely that the olfactory mechanisms are capable of functioning before birth. Since the nasal cavity is filled with fluid, however, olfactory sensitivity is probably not present until after birth. Although several reports on premature infants suggest that they will respond to odorous stimuli (see review by Carmichael, 1946), it is doubtful whether the reactions were actually evoked by stimulation of smell receptors. The stimuli used were ammonia and acetic acid, and, as we know, these are exciters of the trigeminal nerve which happens to be located in the same region as the smell receptors. It is therefore likely that the responses were of a tactual rather than an olfactory origin.

Olfactory Sensitivity in Neonates. Although studies on the status of smell at the time of birth are numerous, the findings—especially in the early studies—are rarely in agreement. Discrepancies are primarily due to the methodological difficulties encountered in the investigations, for it is only recently that techniques have permitted some control over such variables as intensity or duration of odor. Furthermore, many of the early investigators did not take into account that their stimuli might be activating the trigeminal as well as the olfactory nerve. Also, prior to 1930, all investigators neglected to make use of a nonodorous control. In view of these difficulties, we can safely omit the early studies (for review of early studies, see Pratt, 1946).

The first well-controlled investigation was performed by Pratt *et al.* (1930), who used 48 subjects ranging in age from birth to 21 days. The infants were placed in a stabilimeter, and records were made of both gross activity and specific reactions such as sucking and facial expression, in response to ammonia, acetic acid, oil of clove, valerian, and air. Odorous as well as air control stimuli were introduced into the nose by means of a specially constructed olfactory pump. It was observed that, of the total 378 tests, only 48 per cent elicited any activity, and of this activity 59 per cent was in response to ammonia, 33 per cent to acetic acid, 5 per cent to valerian, 3 per cent to oil of clove, and 1 per cent to air. It is interesting to note that ammonia evoked by far the greatest number of reactions and that acetic acid ranked next. Both of these, as we have already mentioned, irritate the trigeminal nerve. On the other hand, valerian and oil of clove, which are generally assumed to stimulate only olfactory receptors, elicited a negligible amount of activity. Thus it seems that the sense of smell is poorly developed at birth. In this experiment, no age differences were noted for the age range studied. In line with the data on taste, Pratt *et al.* observed that the newborn infant does not react to odor in the same way as do adults. Ammonia, which seems much stronger than acetic acid to adult experimenters, elicited about an equal amount of activity in the infants responding to these stimuli.

The only other good study on smell in neonates was done by Disher (1934), who used a procedure similar to that of Pratt *et al.* and also made motion pictures of responses. He studied a group of infants ranging in age from 3 hr. after birth to 10 days. These infants were tested with odorous substances following Henning's classification system—violet, asafetida, sassafras, citronella, turpentine, pyridine, and lemon—as well as a control puff of air. Disher observed that the newborn infants showed a significantly greater number of responses to the odorous stimuli than to the air controls. No age changes in the amount of activity were noted for the 10-day span. Further analysis of the kind of response revealed no differential reaction patterns to the different stimuli.

From the above data, we may conclude that newborn infants react strongly to ammonia and acetic acid; this is not a true olfactory reaction but is due, rather, to the tactual stimulation of the trigeminal nerve. As far as purely olfactory sensations are concerned, present data suggest that they are poorly developed in newborn infants. No differential response to different odorous substances exclusive of ammonia and acetic acid (which produce sneezing, grimaces, and avoidance movements) seems to be present.

Later-age Changes in Olfactory Sensitivity. We are all aware that we can perceive a great many different odors, varying in intensity as well as in kind. Experiments have shown that we are able to detect certain odorous substances in extremely low concentration. We have no data to bridge the span between the poorly developed sense of smell of neonates and the well-developed sensitivity of most adults, nor have we any data on the years beyond maturity. This total lack of experimental evidence is unfortunate, especially in view of the great improvement made in olfactory-testing apparatus in recent years.

Structural Changes in Olfactory Nerves. Smith (1942) reported a very important study of age changes in the olfactory nerve. Since he was unable to dissect out the nerve itself, for various anatomical reasons, he estimated the number of fibers from an examination of the terminal site of the nerve in the olfactory bulb. He examined 205 olfactory bulbs free of intracranial disease, from subjects aged 0 to 91 years. Unexpectedly, he found that loss of fibers begins shortly after birth and continues throughout life at a rate approximating 1 per cent per year. In summary, his results were:

Age	Bulbs examined	Average loss, per cent
0–15	28	8
16–30	27	20
31–45	20	33
46–60	45	57
61–75	55	68
76–91	30	73

This loss in olfactory fibers with advancing age is much greater than for spinal nerves (Cobrin and Gardner, 1937), where a decrease begins only after the age of 30, and where the ultimate loss is 30 per cent as opposed to the 73 per cent reported here. Smith believes that this greater tendency to loss of olfactory fibers may be due to the exposed position of olfactory structures in the nasal cavity—regions which are highly susceptible to inflammatory conditions. No sex difference in the amount of fiber degeneration was noted. One important finding in this study was the great variability of fiber loss at any age, with greater variability in the more

elderly subjects. For seven subjects, all in their 60's, for example, the following amounts of atrophy were noted: 0, 34, 52, 81, 97, 98, and 100 per cent. The wide range (0 to 100) suggests that nasal disease must play some role in determining the amount of fiber loss. In the light of such dramatic structural changes, it is important that research be undertaken to determine whether any correlation exists between olfactory sensitivity and the number of fibers still intact at each age level.

Likes and Dislikes for Odors. Two hundred subjects ranging in age from 7 to 24 years were tested for likes and dislikes of various odors by Kniep *et al.* (1931). Fourteen chemically pure substances were placed in individual bottles, and the subjects were asked to report whether or not they liked the smell of each. No age differences were found; percentages for all substances and for all age groups were of the same order. The investigators concluded that children and adults have similar likes and dislikes as far as odors are concerned.

CUTANEOUS SENSITIVITY

Phylogenetic Aspects. Cutaneous sensitivity involves four senses: pressure, pain, warmth, and cold. A discussion of its phylogenetic development is difficult, because we are not sure what receptors mediate each of these senses. For a long time it was believed that pain was mediated by free nerve endings and the other skin sensations by encapsulated, bulblike organs such as Krause's end bulb, Ruffini's organs, and Meissner's corpuscles. At present there is some doubt about this view. The encapsulated organs are all mammalian structures. In inframammalian species, various kinds of organs are present in the skin. Some of these are free nerve endings, others are knoblike, disclike, or spiral shaped. Whether these simple cutaneous structures have evolved into the complex encapsulated mammalian organs is purely a matter of conjecture. Setting aside this question of specific receptors, let us look at the evidence for cutaneous sensitivity in the various organisms (for summary, see Prosser, 1950).

Pressure-Pain Sensitivity. All organisms are sensitive to pressure or to noxious stimuli in varying degrees. If we stimulate an amoeba by placing a weight on a cover glass, its locomotion decreases, the rate varying inversely with the degree of pressure exerted by the weight. A weak electric current produces movement in the direction of the stimulus, while a strong current results in an avoidance movement. Accordingly, in the amoeba we see an organism whose entire body is sensitive either to pressure or to noxious stimuli. Special receptors are not found until the level is reached at which a nervous system is present. Earthworms, for example, have numerous free nerve endings intertwined around the epithelial cells. These endings have a high excitability threshold, responding only to

noxious stimuli, and thus act solely as pain receptors. In addition, however, the skin of the earthworm contains many sensory cells from which short hairs project. These sensory hairs, at whose base are free nerve endings, spiral and knoblike structures, are quite sensitive to touch. Similar structures are found in many invertebrates. Some of the arthropods such as insects, for example, have sensory hairs on antennae, legs, and wings. Through these, insects are not only aware of direct contact but also of movement of distant objects. Such awareness is mediated through pressure waves acting on the sensory hairs.

Some lower vertebrates such as fishes and aquatic amphibians have a specialized type of tactual organ called *lateral line organs*. They consist of clusters of hair cells usually embedded in the skin along both sides of the body. These and other skin receptors enable the animal to respond to currents of water and also to locate moving objects. In reptiles, the scaly skin limits the distribution of such receptors. In birds, free nerve endings are located at the base of the feathers. Finally, in mammals, we find a variety of skin receptors ranging from free nerve endings to encapsulated organs. This multiplicity is accompanied by highly developed tactual sensitivity. Rats, for example, are capable of discriminating among very fine grades of coarseness (Zubek, 1951).

Temperature Sensitivity. Temperature sensitivity seems to be present in all forms. Many years ago, Jennings (1904) demonstrated that certain protozoa would avoid extremes of either heat or cold, congregating in neutral regions. In some of the lower invertebrates, in fact, thermal sensitivity is acute. Among the annelids, leeches react positively to warm objects and can discriminate temperature changes of 3°. Insects are highly sensitive and hence are easily attracted to warm objects—indeed, it is by this method that mosquitoes and bedbugs can locate human beings in the dark. The thermal receptors of most insects are located in the antennae; a few, like grasshoppers, which orient themselves to the sun, have receptors all over their bodies. Removing the antennae of some insects results in total unresponsiveness to warmth.

In lower vertebrates such as fishes, a number of structures are allegedly sensitive to temperature changes. Among these are the lateral line organs, already mentioned, and a group of bulblike structures located in the head. When electrodes are placed on these bulbs, rhythmic potentials may be recorded which decrease or increase in frequency depending on the rise or fall of surrounding temperature. Differences as small as $\frac{1}{2}°$ can change this rhythmic activity (Sand, 1938). By means of these two mechanisms and perhaps through other structures, fishes can make selective orientations to temperature changes.

In the amphibians, we find the first indication of separate receptors for heat and cold (Morgan, 1922). Stimulating the cold receptors with a 10°

temperature and the warm receptors with a 40° stimulus elicits various spinal reflexes. Through appropriate experiments, Morgan demonstrated that these receptors are distinct from pressure and pain receptors. Very little is known about thermal sensitivity in reptiles. There appear to be
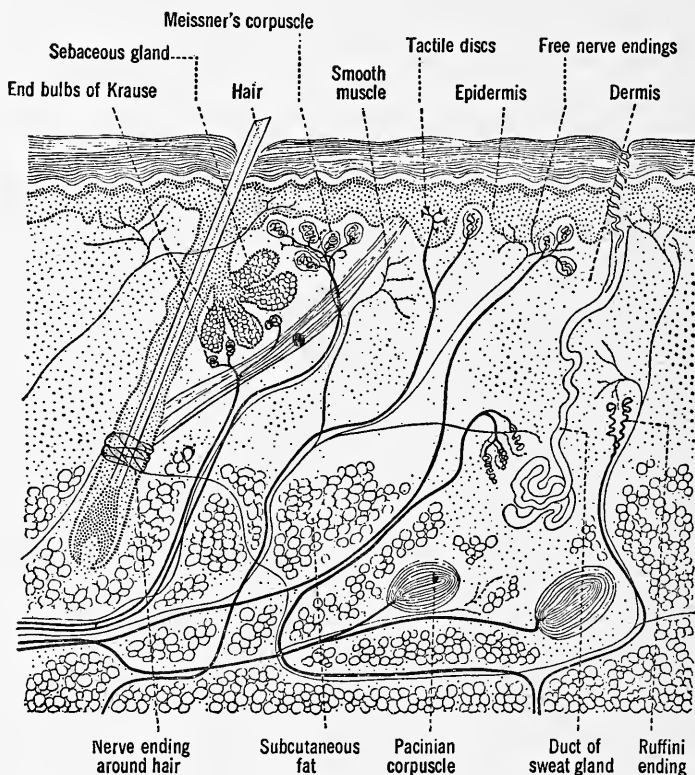
FIG. 66. Schematic drawing of a section of the skin showing various cutaneous sense organs. Not all of these structures are found in any one skin area. (*After Woollard et al. From Gardner, E. Fundamentals of neurology. Philadelphia: Saunders, 1952. By permission of the publishers.*)

receptors which, when stimulated, cause snakes to approach warm objects. When these are destroyed, snakes cease to strike at warm objects and fail to distinguish slightly warm objects from objects at room temperature (Noble and Schmidt, 1937). In both vipers and boas, these receptors are located in pits in the head. Among birds and mammals, body temperature does not passively conform to environmental temperature but remains relatively constant regardless of external conditions. Such regulation is accomplished by a thermoregulating center in the hypothalamus, activated by changes in blood temperature or indirectly through stimulation of thermal receptors in the skin.

Cutaneous Receptors of Human Skin. Figure 66 illustrates a cross section of the human skin, which consists of two layers: an outer *epidermis* and an inner *dermis*. Through the use of appropriate stains, the dermis may be shown to contain a variety of structures—naked nerve endings, bulbs, and corpuscles. Only the most important appear in Fig. 66. Most common are the *free nerve endings*, generally considered to be mediators of pain. In addition, we note a number of encapsulated organs which are of psychological interest. First are *Krause's end bulbs*, not very common over the general skin surface but frequent in certain restricted areas such as the genitalia, nipples, and conjunctiva. They are believed by some investigators to mediate cold. Next are the *Ruffini endings*, less plentiful than Krause's end bulbs and more deeply embedded in the skin. It is thought that they mediate warmth. Then there are *Meissner's corpuscles*, generally found in the hairless regions of the body such as the palms and the soles of the feet. They are believed to be sensitive to pressure. Finally, we have the *Pacinian corpuscles*, the largest of the skin receptors. Since these are usually classified with the kinesthetic receptors, they will be considered later. The above views about the receptor basis of pain, pressure, warmth, and coolness have persisted for many years. Recent research, however, suggests that free nerve endings may mediate all of the various skin sensations, with the encapsulated organs serving as auxiliary structures in some parts of the body (see discussion of Morgan, 1943).

Developmental Changes in Cutaneous Sensitivity

Little is known about the embryological differentiation of the various cutaneous receptors. Present indications are that they may appear earlier than any other sensory structure. Since there is still some doubt regarding which of the skin structures mediate each cutaneous sensation, it may be more profitable to disregard receptors entirely and to discuss the four skin senses in turn.

Early Developmental Changes in Sensitivity to Pressure or Touch. Whether fetuses are or are not sensitive to pressure or touch has been extensively investigated in both animals and human beings (see review of Carmichael, 1946). These studies demonstrate that the human fetus can respond to a light touch stimulus by the third month and that development follows a certain pattern, beginning in the region of the lips and nose and spreading downward in a cephalo-caudal direction. Investigators have worked out quite detailed charts showing the course of development in the guinea pig and the cat. There are also data to indicate that, with increasing age, the fetus is able to make progressively more specific responses to localized stimuli.

In view of the fairly well-developed touch sensitivity in the fetus, we might expect a similar situation in the neonate. Research has corroborated

this expectation. The touch sense is widely distributed at birth, but some parts of the body appear to be more sensitive than others, although no, systematic studies have as yet verified this. Peiper (1928), on a basis of casual observations, believes that the face, hands, and soles of the feet have greatest sensitivity, while shoulders, back, chest, and abdomen are least sensitive.

As language develops, a greater variety of tactual reactions may be studied. One of these is the investigation of the well-known two-point threshold involving measurement of the minimum distance at which two points stimulated simultaneously are perceived as two rather than as one. Brooks (1937) reports that the two-point threshold decreases during childhood. Tactual localization has also been investigated. In these experiments, the subject (with eyes closed) is required to locate a point which has just been stimulated. Renshaw and Wherry (1931), working with a group of boys ranging in age from 6 to 16 years, found that accuracy of tactual localization improves with increasing age.

Later Developmental Changes in Pressure Sensitivity. It is only in recent years that later-age changes have been studied. Perhaps the most important investigation to date was made by Ronge (1943). He sectioned the skin of the finger tips and through histological procedures counted the number of Meissner's corpuscles present at various ages. His results are summarized in Table 10. Children below the age of 10 have roughly 5,600 Meissner's corpuscles in their finger tips. This number decreases throughout preadolescence and later life until the 70's when only 1,000 corpuscles remain. Unfortunately, no corresponding measurements were made of tactual sensitivity. However, Ronge did provide some data on the number of touch-sensitive spots found per square centimeter on the undersurface of the wrist. He found that this number decreased from 53 to 16 spots between the ages of 10 and 80 years. The decrease is attributed to involutionary changes in the receptor structures of skin of the wrist—perhaps to a decrease in the number of Meissner's corpuscles, as shown in Table 10.

Sensitivity of the cornea to touch has also been demonstrated to decline with age (Jalavisto *et al.*, 1951). A quantitative method was developed which enabled the investigators to control the intensity and duration of an air puff directed onto the cornea of the eye. Subjects between the ages of 11 and 81 years were required to report as soon as they noticed for the first time that "something was happening" to their cornea. Sensitivity decreased with age, slowly at first and more abruptly after the age of 50. Jalavisto *et al.* believe that the decrease is related to certain structural changes in the cornea which make it more rigid and more resistant to mechanical deformation.

Vibratory Sensitivity. Age changes in skin sensitivity to vibration have received attention from three groups of investigators. The apparatus used in two of the studies consisted of an applicator from which projected a small rod whose vibration amplitude could be regulated at will. The sensitivity threshold was taken as the value at which a vibration could just be detected. The results of one of these studies (Newman and Cobrin, 1936) are shown in Fig. 67. Vibration sensitivity apparently decreases, gradually and with no abrupt decrease at any particular age, as in many other physiological and psychological functions. In this study, measurements were made only of the skin over the kneecap and ankle. Laidlaw and

TABLE 10. CHANGES IN VARIOUS TACTUAL FUNCTIONS FROM AGE 0 TO 80 YEARS*

Tactual functions	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80
Total number of Meissner's corpuscles in finger tips (approx.)..	5,600	4,900	4,000	3,600	3,000	2,200	1,600	1,000
Number of Meissner's corpuscles per sq. mm. of skin surface of fingers........................	60	30	20	16	13	11	8	6
Number of touch spots per sq. cm. of skin on volar side of wrist....	—	53	35	25	20	19	17	16

* Based on data of Ronge, H. Altersveränderungen des Berührungssinnes. I. Druckpunktschwellen und Druckpunktfrequenz. *Acta physiol. Scand.*, 1943, **6**, 343–352.

Hamilton (1937a), however, extended the evidence in a study in which they sampled the vibratory sensitivity of 76 different points on the body, using two groups of subjects, aged 22 to 28 and 50 to 85 years. Table 11 summarizes the threshold values for 7 representative points. As indicated by higher thresholds, the older group was less sensitive at all 7 points. A similar picture was given of the remaining 69 points tested. One of the interesting findings was that decreased sensitivity was most pronounced in the lower half of the body.

The third study (Pearson, 1928) differed considerably from the first two. A tuning fork with a frequency of 128 cycles was struck and its base placed in contact with a bone. The duration of the vibratory sensation was then recorded. Seventy-two subjects, aged 10 to 90, were used. Vibration sensitivity was gauged at four points: the bones of the forearm, elbow, kneecap, and ankle. According to Pearson, vibration sensitivity reaches a maximum during the adolescent years and gradually decreases thereafter, the decline becoming particularly pronounced after the age of 50. Pearson believes that vibratory sensitivity is present early in life. He cites the case of an 18-month-old baby who looked interested when a nonvibrating

tuning fork was placed in contact with his leg but burst into laughter when a vibrating fork was applied to the same region.

The most likely causes of the decrease in vibratory sensitivity with age are the degenerative changes in the spinal nerves which, according to
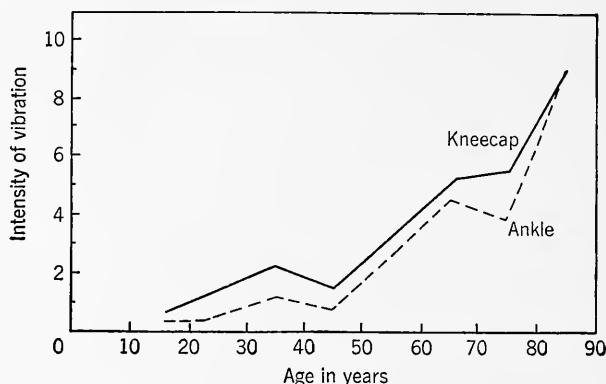
Fig. 67. Age changes in sensitivity of kneecap and ankle to vibration. Intensity is expressed in arbitrary units from 0 to 10. (*After Newman, H., and Cobrin, K. B. Quantitative determination of vibratory sensitivity. Proc. Soc. exp. Biol., N. Y., 1936,* **35**, 274, 275.)

Cobrin and Gardner (1937), begin during the third decade and increase progressively thereafter.

Double Simultaneous Tactual Stimulation. Bender *et al.* (1951), who used a method called double simultaneous stimulation, reported some

TABLE 11. THRESHOLD SENSITIVITY TO VIBRATION AT VARIOUS POINTS IN THE BODY FOR YOUNG AND OLD SUBJECTS*

Age	Fore-head	Cheek-bone	Shoulder	Finger tips	Chest	Thigh	Toes
22–28 years.....	15.2	17.8	20.4	10.6	17.8	39.8	12.0
50–85 years.....	20.4	23.4	36.6	16.4	30.4	76.8	24.9

* Based on data of Laidlaw, R. W., and Hamilton, M. A. Thresholds of vibratory sensibility as determined by the pallesthesiometer: a study of sixty normal subjects. *Bull. neurol. Inst. N.Y.*, 1937, **6**, 502. The figures in the table refer to amplitude of vibration measured in micra.

very perplexing but interesting findings. They studied a large number of cases of children aged 3 to 12 years as well as adults. The subjects closed their eyes; a cheek and a hand or other body part were then simultaneously lightly touched by the experimenter's fingers. Each subject was asked to tell how many points had been touched and to locate them. The

investigators found that for the first several trials both children and adults reported only one sensation—in nearly all cases, the facial stimulus. They referred to this feeling of one sensation as *face dominance*. After a few additional trials, however, adults invariably reported two separate sensations, while in children—especially those aged 3 to 6 years—face dominance continued for many trials over a number of days, and hand sensations were rarely felt. With increasing age, face dominance became less prominent until during adolescence both sensations were reported. Bender *et al.* assure us that these results cannot be explained on the basis of children's lack of attention, for if two tactual stimuli were applied simultaneously to both cheeks, to both hands, or to any other two homologous body areas, the children reported the two sensations correctly. It was only when two *nonhomologous* areas were involved that the phenomenon occurred. Face-hand was the best combination, although foot-hand elicited comparable results. In the foot-hand combination, foot sensation was dominant. These phenomena may be obtained with stimuli other than light touch, for example, with pinpricks or hot and cold objects. Recently, Bender and Green (1952), studying 250 elderly subjects between 61 and 96 years (normals), observed that their responses to the double-stimulation test were similar to those of children of 3 to 6 years.

Interpretation. Bender *et al.* make no attempt to interpret these puzzling findings but merely state that "perhaps after more data are accumulated, a satisfactory theory may be obtained." However, a clue is afforded by some of their data. They observed that in a large number of cases, adult patients with diffuse disease of the central nervous system showed a face dominance similar to the children's responses, while adults such as schizophrenics, manic-depressives, and persons suffering from other nonorganic psychoses failed to exhibit the phenomenon. This suggests that in children face dominance may be related to the relatively immature status of the nervous system. We do know that although most of the tracts of the central nervous system become myelinized quite early, some tracts do not undergo complete myelinization until adolescence. The decrease in face dominance may therefore be correlated with the progressive development of the central nervous system. This view is given further support by the observation that elderly people, in whom we know there are various neural degenerative changes, show dominances similar to those of children.

This does not explain why one part of the body is dominant over other parts, however, or why stimulation of homologous areas fails to produce the phenomenon. Obviously, more research is needed before any complete answer to this interesting phenomenon can be found.

Sensitivity to Pain. Long ago, the philosopher John Locke stated that the fetus was sensitive to pain. Experimental work on premature infants contradicts his statement, for neither pinpricks nor other noxious stimuli

produce much reaction, and frequently even tissue destruction fails to evoke any response.

It is generally agreed that for some hours after birth the neonate is insensitive to pain (see review of Pratt, 1946). Sherman and Sherman (1925) showed that before the age of 6 hr., pinpricks applied to the cheeks, thighs, or calves of the legs elicited no response. Sensitivity to pain increased from this time on, however. The results of their study may be seen in Fig. 68. Although pinpricks elicited no response in an infant 5 hr.
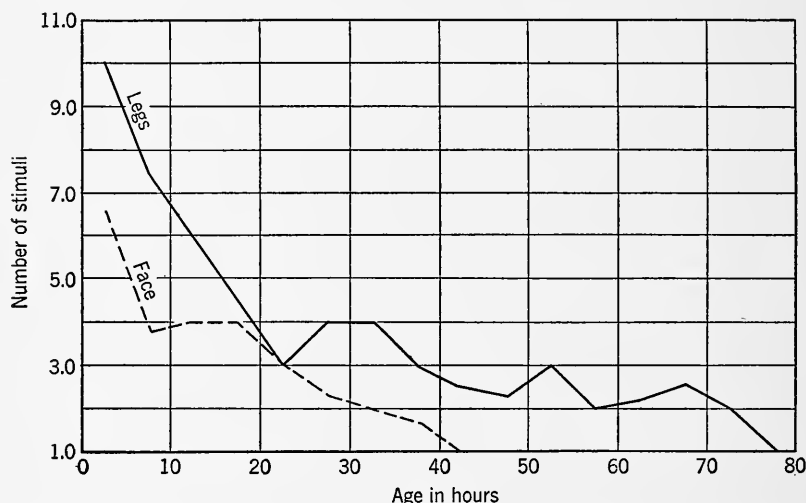
FIG. 68. Response of infants to pinpricks from birth to the age of 80 hr. (*After Sherman, M., and Sherman, I. C. Sensori-motor responses in infants. J. comp. Psychol., 1925, 5, 53–68. By permission of the American Psychological Association.*)

old, a repetition of the stimulus 9 or 10 times in succession did evoke some reaction. By the time the infant was 40 hr. old, only 3 successive jabs were required, and by 80 hr. a response was evoked by a single prick. Sensitivity to pain is greater in the face than in the leg region, as evidenced by the fact that in a 5-hr.-old infant an average of only 6 needle jabs is required on the face as opposed to 9 on the leg. Furthermore, a single pinprick is sufficient at 40 hr. if applied to the face, or at 80 hr. if applied to the leg. These results were verified by Sherman *et al.* (1936) in a later study in which both pinpricks and electric shocks were used. Intensity of stimulation was well controlled in this investigation. The findings showed that with increasing age a lower and lower intensity of noxious stimuli was needed to elicit a pain reaction. Results also corroborated the cephalo-caudal principle, since the head region was most sensitive.

In contrast to the Shermans' findings, Dockeray and Rice (1934) reported that in 4-day-old infants a single needle jab produced a response when applied to any body part. In terms of the vigor and quickness of the

response as determined from photographic records, the leg area was most sensitive and the head region least so. However, in both the Shermans' study and Dockeray and Rice's investigation, the differential sensitivity of various body areas was not very carefully explored. This may explain the opposite findings. Again, at variance with the Shermans' observations, Dockeray and Rice found no age increase in responsiveness. Thus, although there is general agreement that pain is poorly developed in the neonate, there is considerable disagreement over the amount of pain sensitivity present at different ages. Perhaps some of the discrepancies might be clarified if the investigations were repeated using some of the recently developed techniques.

Later-age Changes in Pain Sensitivity. The lone study on later-age changes in pain sensitivity was conducted by Chapman and Jones (1944), who employed the *Hardy-Wolfe* pain-threshold apparatus to test 200 subjects ranging in age from 10 to 85 years. This apparatus consists of an incandescent lamp whose rays are focused on a skin area, usually the middle of the forehead. The test area is blackened to ensure complete absorption and the skin radiated for 3 sec., intensity of stimulation being varied by means of a rheostat. The amount of heat falling on the skin is expressed in terms of gram calories per second per square centimeter of skin surface (gm cal./sec./cm.²). Two measurements were made in this study. The first was of the *pain-perception threshold,* a subjective measure since the threshold is considered as the least amount of heat required to elicit a sharp, jabbing sensation. The other measurement was of the *pain-reaction threshold,* the least amount of heat required to make the subject wince. Chapman and Jones found a pain-perception threshold of 0.289 for ages 10 to 22 years, 0.324 for ages 23 to 44 years, and 0.347 gm. cal./sec./cm.² for ages 45 to 85 years. The age changes in pain-reaction threshold paralleled these. Thus, the data suggest that young people react to pain of a much lower intensity than old people. Once growth is complete, we become more and more insensitive, as revealed by both the subjective reports and the objective threshold values of wincing. The decreased sensitivity is attributed by Chapman and Jones to possible degenerative changes in the pain tracts of the spinal cord and also to "whatever mechanism has to do with decreased alertness on the part of the subject."

Temperature Sensitivity. In addition to attributing pain to the fetus, John Locke also stated that it was sensitive to temperature changes. Although he has been proved wrong on the first count, he was correct on the second. Observations of premature infants have indicated that cold or warm stimuli elicit certain body reactions. It is likely that temperature sensitivity appears early in the fetal stage. Carmichael and Lehner (1937) demonstrated unmistakable temperature reactions in guinea pigs during

the mid-fetal period. Drops of water at body temperature elicited no response, but colder and warmer drops both produced definite reactions.

Sensitivity in Neonates. In contrast to work on the other senses, there is fairly general agreement that neonates are sensitive to temperature stimuli. Early observations have been confirmed by later research (see review of Pratt, 1946). Cold and warm stimuli have been applied to such body parts as the forehead, mouth, tongue, lips, chest, legs, and feet. All parts have responded. Cold stimuli evoke respiratory and circulatory changes such as accelerated breathing and irregular pulse rate, shuddering, throwing the head backward, and withdrawing limbs. Warm stimuli, on the other hand, evoke no such clear-cut changes. While responses to cold stimuli may be roughly classified as avoidance movements, responses to warmth may be considered as adient or approach reactions, for example, turning the head or limbs toward the source of heat. Such responses as shivering or "goose flesh" have been noted soon after birth, but they have been very slight.

Although thermal sensitivity has been demonstrated in neonates, no data are available on later developmental changes.

So far, nothing has been said about accuracy in discriminating small changes in temperature. Studies by Jensen (1932) and Crudden (1937) relate to this problem. Jensen used the specially constructed feeding bottle which he had employed to study taste, and hence was able to record sucking movements. He filled the bottle with milk of varying temperatures, comparing sucking responses of infants aged 2 to 16 days. Some infants made differential sucking reactions to temperature differences of only 8°. Individual differences were great, however, and other neonates discriminated only 17° differences.

Crudden attached metal capsules to the backs of the legs of infants ranging in age from several days to over a month. Changes in temperature stimuli were achieved by passing water of varying degrees of heat through the metal capsules through inlet and outlet tubing. Movies were made of reactions. Of the nine infants tested, two reacted to a change of less than 5° and another four to changes of 6°. Unfortunately, neither Crudden nor Jensen studied age changes in thresholds.

Later Age Changes in Temperature Sensitivity. Just as we lack developmental studies of temperature sensitivity during childhood, so also we lack data on later age changes. All of us have probably noticed that old people are keenly sensitive to shifts in temperature, especially to cold. The only experiments in this field are reported by Krag and Kountz (1950, 1952), who subjected individuals aged 57 to 91 to sessions in very cold and very warm surroundings and compared their reactions with those of a younger control group. It was found that young subjects showed little or no shift in body temperature. Temperatures of the older subjects increased or de-

creased, depending on the environmental change, however. Thus it seems that old people have difficulty in maintaining a normal body temperature of 98.6° in extreme environments.

KINESTHESIS

Kinesthesis, the sense which furnishes information about the position and movements of body parts, is undoubtedly one of the more important sensitivities but also one that is most often forgotten. It is overlooked because it guides our every action and, like the heartbeat, is so continuous that we are normally unaware of it. The sense organs involved are located in muscles, tendons, joints, and the nonauditory vestibular apparatus of the ear, mentioned in the last chapter. Perhaps the main difference between the kinesthetic receptors and the receptors of the other senses is that they are activated from within the body and are always in a state of activity to some degree.

Phylogenetic Aspects. Research on invertebrates suggests that most of the lower forms are probably "aware" of changes in position of body parts. We can record sensory discharges in worms, for example, when parts of their bodies are passively stretched or extended during active movement. Bending the limbs of insects produces a burst of neural activity. Although kinesthetic impulses may be recorded, investigators are still unable to specify which of the numerous sensory structures give rise to the activity at this level of the phylogenetic scale (see Prosser, 1950).

In the lowest vertebrates such as the fishes, we face the same dilemma: we can record sensory discharges from passively stretched muscles, but we can not yet relate them to particular sensory structures. It is not until we reach the amphibians that we can see sense organs, the *muscle spindles*, which give rise to such kinesthetic action. Furthermore, it is only in the mammals that two other kinds of receptors—Pacinian corpuscles and Golgi's tendon organs—make their appearance. These undergo no major changes on the upward scale to man.

Very little work has been done on kinesthetic sensitivity in animals, and what little has been done is confined almost entirely to mammals. Rats are able to discriminate differences in inclination of planes—some can discriminate differences as fine as 1 degree. Cats can discriminate differences of 3 degrees in slope. In primates, kinesthetic sensitivity is highly developed, as evidenced by ability to differentiate slight differences in weight (see Fields, 1942). Crozier (1928) demonstrated the presence of *geotropic responses* (peculiar bodily orientations) in many invertebrate and vertebrate forms. These indicate the existence of kinesthetic sensitivity.

Human Kinesthetic Receptors. Human kinesthetic receptors are of three main types: (1) muscle spindles, located in the fleshy substance of

the muscles and therefore stimulated whenever the muscle is stretched; (2) Golgi's organs, located within tendons at a point where these are attached to muscles, and thus stimulated whenever the tendon contracts; and (3) the Pacinian corpuscles, onionlike structures found in a variety of places such as tendon or muscle sheaves, the regions of joints, and subcutaneous tissues. These receptors are stimulated by depression of the tissues surrounding their immediate locations. In addition to these three receptors, it is believed that certain free nerve endings, especially around blood vessels, may serve as kinesthetic receptors.

When kinesthetic receptors are stimulated, impulses travel centrally to the spinal cord en route to higher structures located mainly in the cerebellum and the cerebral cortex. In this way the brain is informed of the state of activity of the body parts, and can send stimuli back to the muscles, tendons, and joints, coordinating the activities of individual muscles and muscle groups to produce smooth, finely adjusted movements.

Developmental Changes in Kinesthesis. The kinesthetic receptors which have just been described are present during the early fetal period (around 4 months) and are probably functional as soon as movements are observable. Observations on premature infants and on animals indicate that various postural adjustments occur in response to changes of various body parts of the fetus even before birth. Carmichael (1946) states that by the time of birth kinesthetic mechanisms "have undergone such development that they are among the best organized receptor fields so far as the initiation and control of behavior are concerned. Much of the 'movement of the organism as a whole' which so many writers refer to seems to be the result of rather specific kinesthetic stimulation."

There is an almost total lack of experimental data on kinesthetic sensitivity in infants. Casual observation suggests that it is poorly developed at birth and for some time afterward. A small child will often judge a cotton ball as heavier than a wooden one. Judgment is primarily in terms of size rather than weight. Because of this, accidents frequently occur. A youngster will drop an object because he does not know what kind of muscle adjustment is necessary to support the unknown weight. Through experience with toys and other objects, he gradually learns which are heavy and which are light, and also that he can make more accurate estimates of weight if the object is lifted than if it merely remains stationary in the hand.

Discrimination of Weights. Gilbert (1897), who made an extensive study of children aged 6 to 12 years, showed that the ability to perceive small differences in weights of objects of the same shape and size increased rapidly with age. He states that, by the age of 12, children are approximately as accurate as adults in such tasks. No sex differences were observed. Additional data are provided by Terman (1916) in connection

with the revision of the Binet Scale. According to Terman, 70 per cent of 5-year-old children should be able to discriminate between a 3-gram and a 15-gram weight of similar size and shape. By the age of 9 years, 58 per cent should be able to arrange weights of 3, 6, 9, 12, and 15 grams in correct sequence. However, Terman believes that these are chiefly tests of ability to follow directions rather than of ability to discriminate differences in weights.

Later-age Changes in Kinesthetic Sensitivity. The only study of later-age changes was reported by Laidlaw and Hamilton (1937b). They constructed what they called a *kinesthesiometer*, consisting of a series of hinged platforms on which various body extremities could be placed. By means of a crank which raised or lowered the platforms, the subject's joints could be flexed to any angular position. Two groups of subjects were tested—a younger group, aged 17 to 35 years, and an older group, aged 50 to 85 years. Various joints of the body were placed in the apparatus and gradually flexed or extended while subjects were asked to report "up or down" as soon as they could detect the direction of the movement. The angular position of the limb was taken as the measure of threshold. In general, the limbs of the older subjects had to be flexed or extended to a greater degree than the limbs of younger subjects before direction of movement was perceived. The differences were small, however. These investigators report great variability in threshold values in the older subjects. Values of some subjects were on a par with those of the younger controls; in other cases, the threshold values were many times as great. Laidlaw and Hamilton also noted that young subjects made few errors in perceiving the correct *direction* of the motion. Errors of the older subjects were roughly three times as frequent.

LEARNING AND SYMBOLIC PROCESSES

The term *learning* refers to the relatively permanent changes in behavior which result from experience. This excludes behavior altered in consequence of fatigue, drugs, or maturation. To appraise learning ability, investigators have employed devices such as mazes, problem boxes, and puzzles of various kinds as well as the popular "intelligence tests." The rapidity with which a test situation is solved and the complexity of a task mastered are considered indexes of the organism's learning ability, or intelligence.

At the present time, any attempt to separate studies on learning from studies on intelligence would be futile indeed, for many investigators define one in terms of the other. Our division is therefore arbitrary. For convenience, we shall discuss in this chapter the simpler learning tasks and some of the more complex ones involving the so-called symbolic processes. Studies based on the more formal intelligence tests will be deferred to the next chapter. The data of these chapters clearly overlap.

LEARNING AND PHYLOGENESIS

Animals from the amoeba to man have been used as subjects in studies of learning. Of necessity, the techniques employed have had to be adapted to the subjects studied, and accordingly the data assembled are not strictly comparable. Nevertheless, some general statements can be made regarding the correlation between learning and phylogenetic status. First, let us see at what point in the scale learning initially appears and then trace phylogenetic changes.

Appearance of Learning. All organisms from the simple unicellular forms upward are capable of altering their behavior to some degree, as a result of training. There is some question of whether such behavioral changes in the lower invertebrates can be regarded as "true" learning, however.

Buytendijk (1919) studied the *doubling reactions* of the unicellular paramecium. If a paramecium is placed in a very fine glass capillary tube whose diameter is too small to permit the organism to turn around in the

normal manner, it will reverse its direction by doubling its body. It was found that if the paramecium was repeatedly placed in the tube, it reversed its direction more quickly with each insertion. When reversal time was plotted against number of trials, a learning curve similar to that of higher organisms resulted. Buytendijk interpreted this in terms of chemistry rather than of learning; in the course of the paramecium's struggle to reverse itself, chemical changes occurred which cumulatively facilitated reversal.

A second study which demonstrated that the paramecium can retain some of the effects of its previous experiences for as long as 20 min. suggests that chemistry is not the sole explanation of this increased facility, however, and that even in this simple animal we may find rudimentary learning (Day and Bentley, 1911). More recently Gelber (1952) reported what looks like true learning in paramecia. She was able to produce an approach reaction to a bare platinum needle as a result of 40 training trials with a needle baited with food. No such approach reaction occurred in control animals.

Although some doubt exists whether the paramecium's activities represent true learning, it is generally agreed that from the earthworm upward true learning is present. The earthworm has been successfully trained to make consistent right or left turns in a simple T maze and to retain this habit for as long as 3 weeks (Yerkes, 1912). This conclusive evidence is undoubtedly related to the finding that a synaptic nervous system makes its initial appearance in the earthworm.

Simple Learning. Under simple learning we can include the solving of such devices as mazes and simple problem boxes, making conditioned responses, and discriminating various sensory stimuli. By means of one or another of these techniques, learning has been demonstrated in such invertebrates as starfishes, snails, cockroaches, ants, and crayfishes. Among these organisms the highest learning ability has undoubtedly been shown by ants. Ants can solve complicated mazes in 30 or 40 trials if adequately motivated (Schneirla, 1933). Their maze-learning ability is equal to that of many vertebrates. Figure 69 illustrates a maze pattern learned by ants in approximately 40 trials and the learning curve for one of the ants.

Vertebrates have been tested on a variety of problems, including mazes. Generally speaking, their learning ability is of the same order as that of the higher invertebrates. Thus, these simple test situations fail to show any differences attributable to phylogenetic status. Even in the mammalian series we find no significant differences in learning rates on such simple tasks—in fact, rats are superior to college students in speed of maze learning (Lathan and Fields, 1936). In reviewing the literature on learning performance of organisms at various levels of the phylogenetic scale,

Lashley (1934) concludes that "the rate of formation of simple habits has increased little, if at all, through . . . evolution."

Early vs. Late Learning. In his extremely thought-provoking book, Hebb (1949) makes an important distinction between *early* learning and *later* adult learning. The first is "that of the newborn infant or the visual learning of the adult reared in darkness or with congenital cataract; the other, that of the normal adult." Hebb maintains that the reason we see no phylogenetic differences in the learning of simple problems is that we are dealing with adult animals and therefore with later learning. If we were to study the rate of first learning in various animals reared in dark-
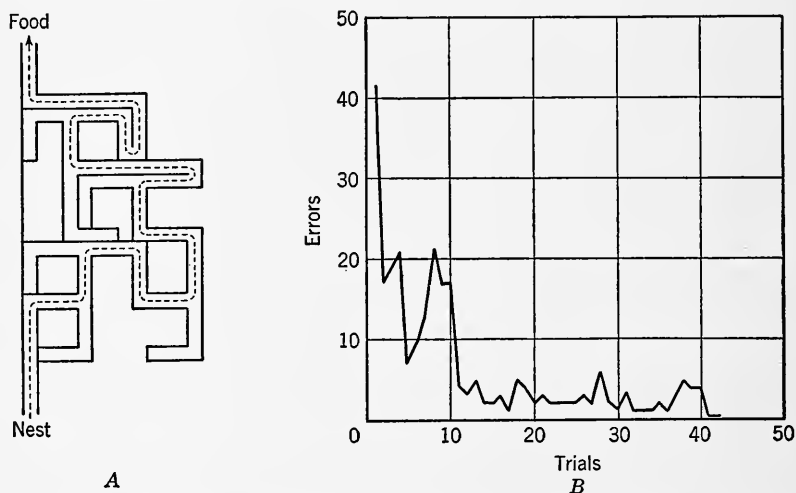
Fig. 69. A maze and the learning curve of it for ants. Note that the shape of the curve is similar to that obtained for maze learning in vertebrates. (*Modified from Schneirla, T. C. Motivation and efficiency in ant learning. J. comp. Psychol.,* 1933, **15,** 245, 250.)

ness to adulthood, however, we should find differences related to phylogenetic status. Several studies support this view.

Rats that have been reared in darkness can learn to make visual discriminations within the first day after removal to a lighted environment (Hebb, 1937). Chimpanzees, similarly reared, require days or even weeks of training to learn such visual discriminations (Riesen, 1947). Human subjects whose vision has been restored after removal of congenital cataracts require months and sometimes years to learn to discriminate fairly simple visual patterns (Von Senden, 1932). Thus, ascending the scale, a slower and slower rate of first learning appears. Adult learning of simple problems shows no such phylogenetic differences.

Complex Learning. Complex learning is quite another matter, and here phylogenetic differences are marked. One of the more complex problems is Jenkins's *triple-plate problem box,* whose solution depends on pressing three

pedals in a certain order. A number of mammals have attempted to solve it. Guinea pigs and rats have difficulty in depressing even one pedal to open a food box. Cats, somewhat higher in the scale, can depress a number of pedals in a definite sequence, such as 1, 2, 3, 1, 2, 3, etc. Primates are capable of solving very complicated arrangements, such as 1, 2, 3, 1, 3, 2, 3, 1 (see Morgan, 1943).

Other complex problems are similarly related to phylogenesis. One example is the multiple-choice problem, in which an animal faces nine compartments, not all used in any one trial. In each trial the animal is required to respond to some constant relation among the compartments, for example, entering the one on the right. More difficult problems may involve choosing the second compartment to the left or right or alternately selecting the left and right ones. Of all mammals studied, only primates are able to learn this last problem. Lower mammals such as rats have difficulty even with the compartment-to-the-right choice. Human beings can solve not only these but also others far more complex (see Munn, 1938).

Symbolic Processes. The ability which seems to have undergone the greatest development during phylogenesis is the one commonly referred to as *symbolic activity*. Symbolic processes are allegedly involved "when the signal or cue for adjustment made is not present at the time of response" (Morgan, 1943). A number of problems are believed to involve symbolic processes. Perhaps the best known is the *delayed-reaction test*, in which the animal is shown a piece of food which is subsequently covered. After a period of restraint, the animal is required to locate the food. The maximum interval of delay followed by success in locating or "recalling" the hiding place is then determined.

Work with this type of problem has been confined to mammals. There is some doubt whether rats can delay more than a few seconds. Primates, however, can successfully recall the site of the food after intervals of delay ranging from several minutes to several days. The chimpanzee can delay for longer intervals than the monkey.

Another problem whose solution is believed to depend on symbolic processes is the *double-alternation* test, or *temporal maze*. In this test the animal is placed in a T-shaped maze and required to learn a series of turns, *e.g.*, LLRRLL, whose sequence is determined temporally rather than spatially (see Fig. 73). This test is thought to involve reasoning. Abilities of the animals studied may be ranked in ascending order as follows: rat, raccoon, monkey, and man. Whatever the process involved, this peculiar ability has undergone considerable phylogenetic development (see Munn, 1938).

Learning Ability and the Nervous System. By way of summary, it may be said that (1) simple problems can be learned as quickly by the lower

as by the higher species; (2) complex problems, especially those believed to involve symbolic processes, are learned more and more readily as the scale is ascended; and (3) first or early learning becomes progressively slower during evolution.

These phylogenetic changes in learning ability are associated with the progressively greater development of the nervous system and especially with evolution of the cerebral cortex. Of the cortical changes, the most marked is the increase in the amount of cortex not concerned with sensorimotor functions. This free, or association, area comprises less than 10 per cent of the entire cortex of the rat, while in man it approximates 85 per cent. Since the amount of cortex free of routine sensorimotor functions increases with phylogenesis, it is conceivable that it becomes more and more concerned with the complex activities just discussed as well as with the higher psychological functions of thinking and reasoning.

HUMAN LEARNING

Maturation and Learning. Before we go on to discuss human learning, it might be well to say a few words about maturation and learning. *Maturation* refers to the development or unfolding of behavioral characteristics which are inherent in the individual because of inherited factors, for example, the physical changes which are associated with puberty or the fairly sudden appearance of locomotor abilities. Learning differs from maturation in that it depends on experience. The two processes are not independent of each other, however; they facilitate or retard one another. Learning has to wait for maturation; the child does not begin to learn until he is "ready" to learn. Physical equipment must have reached a certain functional level before new skills can be built up—learning to read, for instance, begins at a stage of "reading readiness." On the other hand, even inherent characteristics may not develop to the maximum without experience (see also Chapter 6).

Types of Learning

One of the problems confronting investigators in the field of learning is whether learning occurs by one or by several processes. In past years, four kinds of learning have been identified: trial and error, conditioned, insightful, and imitative. Let us examine each briefly.

Trial-and-error Learning. We are indebted to Thorndike (1898) for the first clear account of the trial-and-error nature of a great deal of our learning. Thorndike's views were based on observation of the behavior of hungry cats placed in a problem box from which they could escape only by learning to pull a string, press a lever, or step on a platform. Food was placed outside the box to ensure adequate motivation. Records were made

of the time required for the cats to perform the act which would release the door catch. For a while, a cat would manipulate various things in the box by trial and error, then more or less accidentally he would press the lever or pull the string. After a number of trials he would manage to press the lever with fewer trials and errors. Finally, he would go directly to the lever.

On the basis of this and other experiments, Thorndike formulated what became a very influential theory of learning. It involved such principles as effect, frequency, recency, etc., designed to explain the manner in which errors were gradually eliminated and correct responses fixated during the learning process. Thorndike's theory was well received by educators, for it stressed such things as reward and punishment, repetition or reviewing, and frequency, which supported the idea of drill and accordingly appeared to corroborate what had long been practiced.

Trial-and-error learning appears in the solution of many problems which confront children, especially in the learning of various motor skills. It is clearly evident in children's attempts to solve mazes. Experimental work on this kind of learning will be cited presently.

Conditioning. The idea of conditioning dates from the work of the Russian physiologist Pavlov. Since his time, the CR (conditioned-response) concept has played an important role in theoretical discussions of learning—indeed, a number of theorists in the past have maintained that all learning may be essentially resolved into the acquisition and integration of such responses. Even certain present-day theorists consider the conditioning principles as key elements in their theories of learning.

Conditioning experiments are so generally known that illustrations may be superfluous. When a light is flashed, the pupil of even a young child constricts automatically. This involves no learning. If a bell is rung at the same time as the light is flashed, and if this is repeated several times, the bell alone will soon evoke a constriction of the pupil. Attaching the old response (pupil constriction) to the new stimulus (bell) involves learning, and this kind of learning has been called conditioning.

Evidence suggests that much learning is of this type during the first few years of a child's life. Acquisition of speech depends on it to a great extent. Another early example appears in the feeding situation. When the nipple of a milk bottle is placed in the infant's mouth, it evokes a sucking response. As time goes on, the infant sees the bottle before it makes contact with his lips. Eventually, the mere sight of the bottle at some distance will elicit the sucking movements. Another example may be found in children's fears. The child crawling along the floor reaches out to pat the dog. At that very moment the door slams or another loud noise frightens him. The next time he sees the dog he bursts into loud screams of terror.

Many investigators have explored children's fears, likes, and dislikes

from the viewpoint of conditioning. In one experiment, a 2-year-old was given a combination of vinegar and orange juice which evoked grimaces and shivering (Moss, 1924). This unpleasant stimulus was accompanied by the click of a snapper. About 2 weeks later it was observed that if the snapper was clicked while the child played contentedly, he immediately began to shiver. Interestingly, too, he acquired a marked dislike for orange juice.

The conditioned-response technique has many practical applications. It is frequently used to test the sensory capacities of infants and especially of deaf children. It has also been of considerable value in eliminating fears (see any child-psychology text for illustrations). On the negative side, many of our fears and dislikes have been established through this kind of learning.

Insightful Learning. Study of insightful learning was pioneered by Köhler's (1925) observations on apes. Köhler was impressed by the suddenness with which apes learned to manipulate objects to reach food placed outside their cages. In one instance, he placed food beyond reach outside the cage and left two bamboo sticks, each too short to reach the food, on the floor of the cage itself. The ape tried first one and then the other of the bamboo rods but was, of course, unable to reach the objective. He sat down to survey the problem. Suddenly he got up, seized both rods, quickly joined them, and with this extended tool pulled the food into the cage.

In another situation, a banana was suspended by a string from the roof of the cage. Several boxes, each too low to serve alone as a platform, were left at the ape's disposal. Again the ape unsuccessfully tried each box and went off "to think it over." Again he rose suddenly, stacked several boxes in tiers, and from this extended platform reached the banana.

Köhler called this sudden solution "insightful learning." It is similar to what most of us have experienced as "seeing the point"—an "aha!" experience. Experiments of this kind, carried out with children, will be discussed later. This kind of learning is clearly evident only when all aspects of a problem are placed before the subject simultaneously or almost simultaneously so that he can "put two and two together." In mazes, where only a part of the maze can be seen at any one time, insightful learning does not appear.

Imitative Learning. Although many of the things learned by children are based on imitating actions of older siblings, parents, teachers, or playmates, imitative learning is often overlooked. Imitation may be superficial—for example, tying a shoelace like an older child; most imitation goes beyond this superficial level, however. Girls often model dress, mannerisms, or speech after movie actresses or other women who are in the limelight; boys pattern their behavior after movie heroes, athletes, busi-

nessmen, or others whom they admire. Even adults imitate or identify with persons who occupy positions of prestige in society; they "keep up with the Joneses."

Children are especially prone to imitation, from the time they dress up in mother's best shoes and hat with more than generous applications of make-up to the time when they join the bobby-soxers at high school or the sororities and fraternities at college. They learn such things as morals, etiquette, church rituals, and school behavior through imitation. Accordingly, much of our social learning is imitational, operating on both an ideational and an emotional level.

General Comments. Although the four kinds of learning have been considered separately, this does not mean that learning occurs in one way or another. In most problems, two or three or all kinds are involved. Moreover, it is possible that all of these types may eventually be reduced to one. Some theorists, for instance, explain all learning in terms of conditioned response; others believe that insight is nothing more than rapid trial-and-error learning at an implicit or mental level and therefore not observable until the subject hits upon the correct solution. However, we need not concern ourselves with these theoretical problems.

Simple Learning Processes

Conditioning Studies in Prenatal and Postnatal Periods. When is a human being first capable of learning? Using a conditioned-response technique, many investigators have tried to answer this question. Some failed to demonstrate conditioning in the fetus (Ray, 1932; Sontag and Wallace, 1934). Spelt (1948), however, reported success with fetuses of 6½ to 8½ months. The original stimulus in this study was a loud sound; the conditioned stimulus, a tactile vibration applied to the mother's abdomen. After 100 paired presentations, fetal movements followed the vibration alone.

There are two reports of successful conditioning of neonates within 10 days after birth. In the first, sucking was established in response to the sound of a buzzer in seven out of eight neonates (Marquis, 1931). In the second study, eyelid closure was conditioned in response to vibration applied to the foot in three infants as early as the fifth day after birth (Wenger, 1936).

These findings, suggestive of conditioned learning in the fetus and neonate, are seriously challenged by the excellently controlled investigation of Wickens and Wickens (1940), who divided 36 infants under 20 days of age into an experimental and a control group. The experimental subjects were given 36 paired stimulations of electric shock to the sole of the foot accompanied by the sound of a buzzer and were subsequently tested by the sound of the buzzer alone. Nine out of 12 infants withdrew the foot at

the sound of the buzzer. Continued presentation of the buzzer sound alone elicited fewer and fewer reactions, and finally complete extinction of the response occurred. When the buzzer was sounded again the following day, however, the withdrawal response reappeared. Conditioned response, extinction, and spontaneous recovery were thus demonstrated.

The amazing results in the Wickens investigation were obtained from the control group, however. The controls had been given 36 foot shocks alone and had not at any time heard the buzzer. When the crucial test of sounding the buzzer was made, 10 out of 12 subjects responded by withdrawing the foot just as the previously conditioned experimental subjects had done. Extinction followed by spontaneous recovery the following day was exhibited by the controls also.

In view of these surprising results, it is doubtful that true conditioning has been demonstrated in neonates, and this, of course, reopens the whole question of the "conditionability" of either fetus or neonate. One fact becomes clear from the Wickens study: future investigations must be very carefully controlled.

Conditioning Studies in Older Children. Studies of conditioning of older children are numerous. In one investigation, 16 infants aged 1½ to 4 months were given paired presentations of feeding bottle and a buzzer (Kantrow, 1937). After anywhere from 16 to 72 such presentations, the buzzer alone elicited conditioned feeding reactions. Similar sucking reactions have also been rapidly established in response to tones of different intensities and to light in infants of 1 to 2 months (Kasatkin and Levikova, 1935a, 1935b). Other investigators have evoked reactions such as blinking, limb withdrawal, and galvanic skin responses as a result of visual, auditory, and tactual stimulation in children under 1 year of age (see review of Munn, 1946). In young infants, these conditioned responses are not too stable. With increasing age, however, responses become more enduring, and some reactions conditioned in infancy have been retained for periods up to 7 months (Jones, 1930).

Literature covering studies of children over 1 year old is also prolific. The consensus of findings leads us to conclude that susceptibility to conditioning increases up to the fourth year, after which it begins to diminish, continuing to decline to adulthood (Mateer, 1918; Osipova, 1926; Dernowa-Yarmolenko, 1933). One writer interprets this reversal around the age of 4 as a result of attitudinal factors beginning to develop around that time (Razran, 1935). According to this authority, older subjects are not less able but less willing to submit to the usual conditioning procedures as they grow less and less naïve.

Learning of Motor Tasks. Acquisition of a variety of motor skills is important to children, for without them it would be difficult indeed to orient to the environment. Mention has already been made of a number of

basic motor skills—crawling, walking, etc., as well as development of prehension and manipulation. While practice is important in the acquisition of these skills, such studies as McGraw's of Johnny and Jimmy support the view that maturation plays an important, and perhaps a major, role. In this section, we shall be more concerned with motor tasks which have a large learning component.

Maze Learning. The relationship between chronological age and maze-learning ability has received considerable attention. Variables tend to be confusing, however, for although improved scores on maze performance may depend on increasing maturation of the nervous system, they are just as likely to depend on greater interest, longer attention span, or the experience accompanying advancing age. To ensure that such variables as motivation, attention, and previous training are similar for the different age groups is extremely difficult, if not impossible. Experiments have shown that all these can and do markedly affect the course of learning.

In discussing phylogenesis, we observed that the ability to learn simple tasks such as mazes shows little or no improvement during evolution. A similar situation prevails with respect to ontogenesis. An early study illustrates both of these points (Hicks and Carr, 1912). In this study, a group of university students were compared with a group of younger subjects aged 8 to 13 years and, interestingly, with a group of white rats which performed on a similar maze of smaller dimensions. The results of this study are shown in Fig. 70. Most striking is the finding that the performance curves of adults, children, and rats are very nearly identical. Each curve shows a rapid initial decrease in number of errors, time, and distance traveled; in each curve, this rapid drop is followed by more gradual improvement in performance. After surveying the literature on maze learning in children, Munn (1946) states: "The analysis of results of these investigations fails to reveal any consistent evidence of age changes in maze-learning ability."

Learning of Other Motor Tasks. For simple motor tasks, the consensus of studies to date is in line with findings on maze learning. Both initial and final performance improve with increasing age, but the *rate* of learning resulting from a given amount of practice does not appear to change much. In reviewing studies of such simple tasks as localizing a point on the skin, hitting a moving target, mirror drawing, and pursuit meters, Munn (1946) sums up: "One is forced to conclude that if the learning of such motor skills as have so far been studied improves with age, the results fail to show clear evidence of it." Later we shall see that learning of more complex motor tasks involving symbolic processes such as reasoning does show pronounced age changes.

Problems Involving Insight. So far, we have been concerned primarily with learning of a trial-and-error variety. Several investigators have also

reported on problems believed to involve insightful learning—most of them similar to the tasks Köhler gave his apes.

Perhaps the most extensive of such studies was done by Alpert (1928), who presented three problems to 44 children aged 1½ to 4 years. In the first problem, an object such as a toy airplane or balloon was suspended from the ceiling, out of reach unless the child made use of a box left in one corner of the room. In the second, a toy was placed out of reach outside the play pen, but a stick was left within reach. The third situation resembled
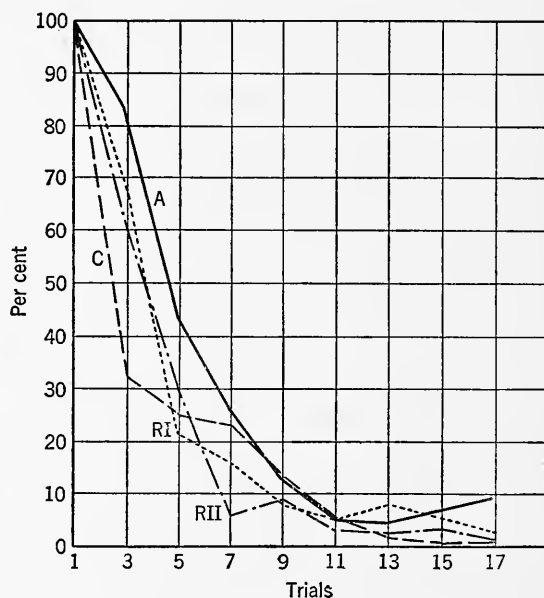
FIG. 70. Curves for maze learning in rats, children, and adults. *A*, adults; *C*, children; *RI*, *RII*, two groups of rats. The curves are based upon reduction in time, errors, and distance traveled, these three measures being combined to give a composite score. Improvement in performance is shown as the percentage reduction of the scores made on the first trial. (*From Hicks, V. C., and Carr, H. A. Human reactions in a maze. J. anim. Behav.*, 1912, **2**, 109.)

the second except that this time the toy was placed further away and could be reached only by joining two sticks. At first, all children exhibited a certain amount of trial-and-error behavior. Sooner or later, however, they appeared to perceive the crucial relationship between tools and the desired objects and hence quickly brought in the toys.

In some children trial-and-error behavior was less evident, while in others it persisted through a number of trials before any sudden solution occurred. The children's behavior was essentially similar to that of Köhler's apes except for two factors: (1) children engaged in considerable verbalization, talking to themselves and to the experimenter; (2) frequently they attempted to utilize social aids, by asking, for example, "May I have

the other stick?" They also used indirect methods, such as looking at the experimenter's face before trying a new technique, and emotional appeals, such as crying. An important finding was that once a solution had been reached, children lost little time in transferring the essential principle to other situations which varied only in detail. There was some evidence of improved insightful learning with increasing age.

A clearer picture of developmental changes in insightful learning is given by Matheson (1931), however. The 28 subjects of this study, aged 2 to 4½ years, were given problems similar to Alpert's group as well as several others. The percentage of children able to solve these problems increased from 0 at age 2 to 62 per cent at 4 years.

It has been claimed that infants even under 12 months of age show insight. Beginning with 7-month-old infants, Richardson (1932) gave monthly tests using a number of string problems whose essential feature was a toy attached to a string within easy reach. Interest in the toy was aroused by squeaking the rubber cat, etc., and then the string was placed beside the child within easy reach. It was observed that, with advancing age, children appeared to pass through the following stages: (1) interest in the string rather than in the toy, (2) interest in the toy and accidental contact with the string, and (3) drawing in the toy. The third type of reaction was established by 11 months. It is considered by Richardson as indicative of "insight," since all children had to perceive and utilize a crucial relationship before they could solve the problem. The cumulative weight of evidence thus suggests that learning by insight is present in infancy in at least rudimentary form and that it improves with age.

Learning of Verbal Materials : Language

Because the development of language is so important to human living and because some phases are easily studied, there is a tremendous amount of literature in this field. Language, once acquired, changes little with advancing age, however, so that the topic is well covered in many sources (for an excellent review see McCarthy, 1946). For this reason, and not because it is unimportant, only a few studies will be scanned here.

Development of Oral Language. The vocal organs are capable of producing sounds long before birth. Sounds have been noted, for instance, in prematurely delivered fetuses during the fifth month (Minkowski, reported by Carmichael, 1933). Although the vocal mechanisms thus appear to be ready for activity, language as we know it depends on environmental stimuli peculiar to the postnatal period. Language is therefore a learned skill.

The Prelinguistic Period. It is generally agreed that speech evolves from the expanding repertoire of sounds which the infant can make long before words are either understood or uttered. These early vocalizations are

probably reflex in nature and entirely meaningless. Various observers have noted that between the second and fifth weeks the cries and other vocalizations begin to differentiate, however, and certain sounds may occur more and more frequently in response to specific stimuli such as hunger, pain, or other discomforts (O'Shea, 1907; Blanton, 1917; among others).

It is also unanimously agreed that vowel sounds precede consonants. A repertory of over 1,000 vowels uttered during the first 10 days was reported by one investigator who used a phonographic recording technique to analyze the emergence of various sounds in a group of 40 neonates (Irwin and Curry, 1941). No sex differences were observed. Interestingly, too, a later study estimated that normal infants 1 month old had a vowel-consonant ratio of 4:1 but that this ratio decreased with age. Four-year-old feeble-minded children whose IQ's ranged from 7 to 48 continued to have a high vowel-consonant ratio of 2:1 as compared with a normal ratio of 1:1. Thus the speech of feeble-minded children is retarded as compared with their own age group (Irwin, 1942).

Once sounds have been acquired, they differentiate rapidly, and by the third and fourth months voluntary cooing and gurgling are common. There are various views concerning subsequent progress from babbling, through repetition, or *echolalia*, to speech. According to Latif (1934), for example, "Almost as soon as sounds begin to be produced at all they begin to be repeated rather slowly and monotonously . . . . This repetition, or reduplication, may well be considered the final step in that process by which the mere vocalizations become organized into language. It is here that explanation of the development of language must begin."

If, at this point, we recall the controversial schools of thought mentioned earlier (*i.e.*, individuation vs. integration), we can accurately anticipate that the controversy extends to language as well as to principles of general development. Dewey (1935) sums up this problem very well:

There are a number of theories as to the way in which speech develops from the early vocalizations. In general, two opposing points of view appear: one, that learning goes on by a very gradual process of building up the complex from the simple; the other, that the original phonetic equipment of the individual is very large, and that learning takes place by a process of adjusting and eliminating the sounds used to the language learned. . . . Gregoire . . . believes that the sound repertoire of the young infant is phonetically great and that a particular language evolves by the elimination of some sounds. The first sounds the infant makes are uncoordinated and precision is gained gradually. In the beginning, the infant tries hard to express himself without awareness of trying to use words. He usually ends up by crying. Later, about the ninth month, the combination of syllables begins. This sounds in its rhythm like an imitation of adult speech, and in the tenth month he begins to imitate the rhythm of the language of his country . . . [p. 252].

In commenting on the various theories of linguistic development, McGranahan (1936) emphasizes their psychological and physiological counterparts. On the one hand, the so-called "root" theory corresponds to the reflex theory of behavior which stresses the integration of several elementary reflexes to produce more complex patterns. On the other hand, the "mass" theory is analogous to the "modern psychological conception of behavioral development as the progressive differentiation of original mass activity."

Comprehension vs. Expression. Children understand language before they can express themselves in words. Many investigators believe that comprehension begins around the ninth month, as evidenced by attentiveness. By the end of the first year, overt responses to commands and questions are common. It is generally agreed that gestures are understood long before spoken words and that intonation and the situation itself contribute more to dawning comprehension than the words themselves. Lewis (1936) distinguishes three developmental stages:

1. An early stage, during which the child discriminates between different patterns of expression and intonation.

2. A second stage, during which intonation dominates over the phonetic form.

3. A third stage, during which phonetic pattern gains ascendancy over intonation, although the influence of intonation continues to persist.

As has already been observed, meaningful speech follows comprehension. In his early babblings the child may repeat syllables such as dada, mama, or papa, but it is doubtful whether he attaches significance to them. Because of these babblings, however, it is difficult to say when words become meaningful and hence constitute true language. Several investigators have attempted to approximate the age at which the average child has acquired a one-word vocabulary. In general, estimates range from 11 months to 1 year. Expressive language thus commences with the second year.

The Growth of Vocabulary. Comprehension continues to develop more rapidly than the expressive side of language, and it is common knowledge that we recognize more words than we use at any age. The rate of development of both comprehension and speech, however, depends on a number of variables, such as the IQ of the child, and environmental influences, such as socioeconomic background, parental education, and number of siblings. Of the many studies in this field, we can mention only a few— all of which are handicapped by the difficulty of devising valid tests.

Extent of Vocabulary. In estimating the growth of vocabulary, perhaps the most reliable data were reported by Smith (1926). In this study, children aged 8 months to 6 years were required to name various objects shown in pictures. If a child failed to use the test word in response to a

question about the picture, another question was given, and credit was allowed for evidence of knowledge indicated by response to either question 1 or question 2. Table 12 records the extent of such vocabulary for the age groups tested.

According to Table 12, the subjects recognized several words at the age of 1 year. The rate of increase was slow at first, increasing rapidly during the third, fourth, and fifth years to reach a total of over 2,500 words

TABLE 12. INCREASE IN SIZE OF VOCABULARY IN RELATION TO AGE*

Age		N	Average IQ	Number of words	Gain
Years	Months				
0	8	13	—	0	
0	10	17	—	1	1
1	0	52	—	3	2
1	3	19	—	19	16
1	6	14	—	22	3
1	9	14	—	118	96
2	0	25	—	272	154
2	6	14	—	446	174
3	0	20	109	896	450
3	6	26	106	1,222	326
4	0	26	109	1,540	318
4	6	32	109	1,870	330
5	0	20	108	2,072	202
5	6	27	110	2,289	217
6	0	9	108	2,562	273

* From Smith, M. E. An investigation of the development of the sentence and the extent of vocabulary in young children. *Univ. Ia. Stud. Child Welf.*, 1926, **3**, No. 5, 54.

by the age of 6. IQ ratings indicate that the children were of normal intelligence.

Although the actual numbers of words reported by various investigators differ slightly, the general growth trends in vocabulary are similar. We may clarify this point by comparing the data of Table 12 with the graphical representation in Fig. 71 (Morgan, 1942). According to both studies the growth rate is slow at first but increases with advancing years. Figure 71 extends the data to adulthood. It is interesting to note that vocabulary size continues to increase well on into adult years. The rather startling discrepancy between the number of words recognized and the number of words actually used at each age level is also well illustrated in Fig. 71. Even in adulthood, we seemingly adhere to our limited jargon orally, even though we are familiar with a greater repertory of words and are capable of more vivid and picturesque speech.

Sentence Length. Another approach to the study of language development is the measurement of the mean length of sentences spoken at various ages. Such studies are ably summarized by McCarthy (1946). All investigations indicate an increase in sentence length throughout the preschool and elementary-school years. Smith (1926), for example, reports a mean length of 1.3 words at 2 years, 3.3 words at 3 years, 4.1 at 4 years, and 4.7 at 5 years. Although means differ to some extent, others report similar trends (McCarthy, 1930; Day, 1932; Fisher, 1934). Several investigators point out that children use longer sentences when addressing adults than when speaking to other children (Smith, 1935, among others), and
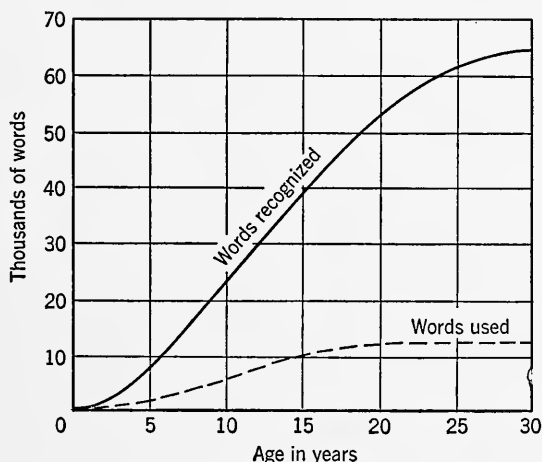
Fig. 71. Growth in general vocabulary from infancy to adulthood. (*From Morgan, J. J. B. Child psychology. New York: Rinehart,* 1942. *P.* 307. *By permission of the publishers.*)

that girls use longer sentences than boys (Smith, 1926, 1935; McCarthy, 1930; Day, 1932). It is also worth noting that sentence length correlates highly with intelligence.

Development of Written Language. Written language involves not only a knowledge of words but also considerable finger coordination. As might be expected, writing is therefore a learned skill appearing much later than speech. For most children, writing begins when they start school. Data in this field are thus limited to older subjects.

A study of 814 children ranging in age from 8 to 14 years was reported by Heider and Heider (1940). These children were requested to write a short composition about a movie, and the number of words per sentence was noted. The average 8-year-old (grade 3) used 10.2 words per sentence as compared with 11.1 words at 10 years, 12.8 words at 12 years, and 13.9 at 14 years (grade 9).

These findings were supplemented by Stormzand and O'Shea (1924),

who collected 10,000 sentences drawn from compositions and letters of individuals aged 12 to adulthood. They reported slightly longer sentences at all age levels than did Heider and Heider. At age 12, for example, Stormzand's sample averaged 13.5 words, and at 14 years, 17.3 words, as compared with the 12.8 and 13.9 recorded by Heider and Heider. At later age levels, Stormzand's subjects averaged 17.8 for grade-10 students, 18.0 for grade 11, 19.8 for grade 12, 19.9 for college freshmen, 21.5 for college seniors, and 20.9 for adults. The discrepancies between the two studies may be due to several factors such as differences in IQ, socioeconomic level, and parents' education. Regardless of the precise figures, however, both studies point to a definite trend toward increasing sentence length from the time of earliest writing to adulthood.

Age Changes in Parts of Speech. Many attempts have been made to explore age changes in the various parts of speech used in both oral and written work. Young (1941) states: "The proportions of the parts of speech changed most rapidly before the age of 3, and after that age the rate of change tended to be slower." However, Young herself, as well as other investigators, stresses the fact that as soon as the child attains the use of complete and grammatically correct sentences, the percentages of the various parts of speech are determined by the conventions of the language itself, and hence developmental trends become insignificant. This is especially true of written language.

During the earliest years, the child uses a preponderance of concrete nouns which may be readily associated with objects. Thus "drink" or "milk" may signify the liquid but may also represent in a single word "I am thirsty." "Bed" may mean bed or it may mean "I am tired," "I am sleepy," or "I want to go to bed." Accordingly, it is logical that as new words are acquired speech proportions should change rapidly. In the light of recent findings in the field of intelligence testing, it might also be suggested that word usage may be more dependent on family background and education level than on chronological age.

Egocentric vs. Socialized Speech. Some years ago, Piaget (1926) launched a controversy which has continued over the years, when he asserted that the speech of a young child is egocentric in nature. To Piaget, egocentric speech meant that "the child does not bother to know to whom he is speaking nor whether he is being listened to. He talks either for himself or for the pleasure of associating anyone who happens to be there with the activity of the moment. . . . He does not attempt to place himself at the point of view of his hearer." Conversely, socialized speech was speech "in which the child addresses his hearer, considers his point of view, tries to influence him or actually exchange ideas with him." According to Piaget, the child's speech becomes progressively more socialized, especially during the seventh and eighth years.

Other investigators have attacked Piaget's viewpoint and have provided evidence to refute his findings (McCarthy, 1930; Day, 1932; Smith, 1935; etc.). Johnson and Josey (1931), for example, in summing up their work, state that "instead of finding them egocentric we found them socially minded, willing and able to assume the position of another and even that of any hypothesis. They were able to make themselves understood . . . . Six-year-olds, he (Piaget) tells us, cannot reason because they are too egocentric. We found nothing in our investigations to support this view. On the contrary we found all of our children to be socially minded and in no manner dominated by an egocentric attitude."

After reviewing the literature on this topic, McCarthy (1946) concludes that "it should be pointed out . . . that even the highest estimates of egocentricity rarely exceed 30 per cent and hence the enthusiastic statements one occasionally finds regarding the predominance of egocentrism in the speech of young children are quite unfounded." Although studies on speech are lacking, evidence on age changes in interests suggests that if any period may be classified as egocentric, it is extreme age rather than extreme youth (see Chapter 13).

Other Verbal Materials. So far, our discussion of language development has been restricted to the learning of oral and written symbols. Other kinds of verbal learning have been studied—nonsense syllables, prose vs. poetry, etc. Since both speech and other verbal materials involve memory, we shall defer further discussion to later sections.

Variables Affecting Learning

Apart from age, other variables such as sex, IQ, and motivation affect all learning. For convenience, this discussion will be arbitrarily divided into two parts, dealing with the effect of such variables on (1) motor tasks and (2) language.

Variables Affecting Learning of Motor Tasks. An excellent summary of the effects of such variables as sex, IQ, and various incentives on tasks such as maze learning and target throwing has been presented by Munn (1946). In general, no sex differences are observed for such simple motor tasks. Studies of the relationship between intelligence-test scores and motor tasks of the type mentioned have indicated little or no influence of intelligence on such learning up to the age of puberty.

Research on adolescents is out of line with this generalization. In one investigation, for example, where both blind and seeing adolescents were tested on a stylus type of maze and on a raised-finger maze, correlations ranging from $-.61$ to $-.75$ between IQ and number of trials and errors were reported (Knotts and Miles, 1929). Thus it seems that by adolescence the brighter individuals make fewer trials and errors in learning mazes. Work on incentives such as praise, reproof, and various material

rewards such as candy or money indicates that performance improves as a result of incentives in both motor and verbal tasks.

Variables Affecting Learning of Language. The relationship between learning of language and of motor skills has been explored extensively. Shirley (1933a, 1933b) made a careful analysis of the motor development of 25 children on whom she also kept language records. She found a cyclical relationship between these two phases of development. Frequency of vocalizations decreased during the periods when the child was learning to reach for objects, to sit alone, or to walk. All correlations between scores on locomotion or prehension and vocalization were low and of a negative order. Shirley concludes that "speech development is held in abeyance at the time when motor progress is most rapid" and that "babbling is a type of behavior which the baby resorts to when there is nothing better to do or when the novelty of a new type of motor activity has worn off."

As soon as the basic elements of both speech and motor activity have been mastered, this picture changes. Wellman *et al.* (1931) found a correlation of $+.67$ between scores obtained for tracing a path through a maze and the total number of sounds uttered and a correlation of $+.65$ between tracing a path and the number of consonant blends articulated by children. A high positive correlation has also been reported between language development and fine motor coordination (Shirley, 1933b) and between the use of things and talking about things in nursery school (Fisher, 1934; correlation $+.86$). In interpreting these and other data, McCarthy (1946) suggests that since articulation is also a motor function, the high positive correlations may signify a general motor ability, or, on the other hand, both may be highly related to chronological age.

Mental Age and Language Development. While most studies of language and motor abilities in young children do show some relationship, the extent of the correlations appears to depend on the type of motor task measured and on the particular facet of language appraised. A more clear-cut relationship is reported between mental age and language. This is probably due to the fact that present-day intelligence tests have a large language component and, with rare exceptions, depend on language to convey instructions. As an example of these studies, let us look at the correlation coefficients reported by Williams (1937):

> MA–speech sounds.............. $+.12$
> MA–word usage................. $+.49$
> MA–length of unit.............. $+.78$
> MA–completeness............... $+.55$
> MA–vocabulary
>   Van Alstyne scale............. $+.52$
>   Smith-Williams scale.......... $+.47$

Sex Differences in Language Development. Studies of sex differences in language development provide fairly consistent evidence that girls pro-

gress faster than boys in this respect. The cliché that "women are naturally more talkative" is probably untrue, however. The reason is more likely to be found in the earlier maturation of girls and in the social mores which have in the past emphasized athletic prowess for boys only, thus leaving more time for linguistic activities for girls. It is interesting that while girls show greater facility in linguistic tests, most of our great authors of past generations have been males.

There is not yet sufficient evidence in this field to show whether sex differences derive from physical, mental, emotional, or social sources or perhaps from a combination of all these. It is interesting, however, that sex differences are more marked among children of the lower socioeconomic levels (Davis, 1937; Young, 1941).

REMEMBERING

So far, we have been concerned with the acquisition of various materials. Next to be considered is how well these materials are retained or remembered. Retention may be measured in a number of ways such as accuracy of reproduction, recognition of once-learned material, or the saving of time when materials are relearned. Literature in this field is extensive. We are interested primarily in the studies which picture developmental aspects of the memory process.

Appearance of Memory in Infants. At what age does the infant show the first signs of memory? This question has always interested parents. Because of the infant's inability to verbalize, various indirect means have been used to test memory at this age level. Charlotte Bühler (1930), for instance, devised several tests for infants under 12 months of age. In one of these, the face of the experimenter appears and then disappears. If the infant searches for the face or is disturbed in any way, he is given credit for memory. Bühler found that infants of 3 months became agitated over the withdrawal of the face.

A different test was employed with older infants. They were given a ball constructed in such a way that a chicken popped in and out when the ball was squeezed. When this had been done, the child was given another toy. After variable periods of time, the ball was returned but the chicken was missing. If the child registered astonishment or was puzzled when he squeezed the ball and the chicken failed to emerge, he was credited with memory. Bühler claimed that infants aged 10 to 11 months gave evidence of memory after a delay of 1 min., children aged 15 to 17 months after 8 min., and children of 21 to 24 months after 17 min. Studies of this kind have one weakness, however, since the experimenter has to depend on facial expression and movements as evidences of memory.

Recall Memory. One of the most extensively used methods of studying memory is the recall technique, in which subjects are asked to reproduce

the correct response previously presented. This method has been used to appraise memory for digits, words, nonsense syllables, poetry, narratives, etc. School tests furnish a common example.

Memory Span. One of the simplest tests of memory span is appraisal in terms of the number of words or digits reproduced correctly after a single brief presentation. As might be anticipated, memory span varies with the kind of material as well as with the age of the subject.

FIG. 72. Growth of memory for concrete words, abstract words, and ideas in stories (logical memory). (*After Pyle. From Cole, L., and Morgan, J. J. B. Psychology of childhood and adolescence. New York: Rinehart, 1947. P. 291. By permission of the publishers.*)

Memory span for digits has been most extensively investigated. Starr (1923), who studied 2,000 children ranging in age from 4 to 15 years, found that a child of 4 or 5 years could repeat 4 digits; ages 6 to 8, 5 digits; ages 9 to 12, 6 digits; and ages 12 to 15, 7 digits. The norms established by Terman and Merrill (1937) in the Stanford revision of the Binet intelligence tests are in close agreement with these findings. Terman and Merrill further state that a superior adult can repeat 8 or 9 digits.

Norms for length of sentences recalled at different age levels have also been established (Terman and Merrill, 1937). At 3 years, a child accurately recalls 6- to 7-syllable sentences; at 6 years, 16 to 18 syllables; at 10 years, 20 to 22 syllables; and at 16 years, 28-syllable sentences. Pyle (1925), who studied over 4,000 boys and girls, found an age increase in the number of concrete and abstract words and also in the number of ideas which could be reproduced after a single oral reading of words or passages. Figure 72 shows the gradual increase in memory for these three kinds of materials from age 8 to 18 years. The increases parallel the growth curves for other intellectual functions during these years.

Memory span has also been determined for letters, nonsense syllables, figures, pictures, movements, commands, and a variety of other materials (see review by Hurlock and Newmark, 1931). The span for each of these increases during childhood. Apart from age, most investigators also ob-

tained medium-order positive correlations with intelligence level. Depending on the type of materials used, the correlation coefficients ranged from $+.40$ to $+.76$. Thus memory span depends on both age and IQ. Probably the increasing ability to pay attention to stimuli and increasing facility with language also contribute to the increased scores.

Recall of Pictures or Events. Some very interesting studies have been done on the ability to report what one has seen in a complex picture, movie, play, or pantomine. Such situations resemble the courtroom scene in which a witness is asked to relate the details of a crime or accident.

In one such study, a picture was shown briefly to 200 children (aged 3 to 8 years) who were subsequently asked to recall what they had seen. The picture included only simple items, well known to children of these ages, and with names within their vocabulary range. Table 13 records the age

TABLE 13. AGE CHANGES IN THE ACCURACY OF RECALL OF ITEMS IN A PICTURE*

Age level, years	N	Average number of items reported, first test	Correct answers	Average number of items reported, second test
3–4	10	8.3	13.2	10.9
4–5	20	16.1	22.5	21.3
5–6	20	26.5	27.7	34.5
6–7	20	30.0	31.7	43.2
7–8	20	35.6	34.3	45.1

* Based on data from Winch, W. H. *Children's perceptions*. Baltimore: Warwick and York, 1914.

changes in the average number of items reported as well as the number of correct answers given to direct questions about the picture. As this table indicates, there is a gradual increase from 8.3 items to 35.6 items recalled, and from 13.2 to 34.3 correct answers to questions. A second recall test given a week later revealed a similar age increase in correct recall, but the interesting thing about this retest was that scores were higher than on the first test. Such improvement in memory with lapse of time is called *reminiscence*. This will be discussed later. On this particular test, the improved scores may have resulted from such factors as discussion among the children and from implicit rehearsal during the week (Winch, 1914).

These data may be supplemented by two other studies which extended the age range to 20 years (McGeoch, 1928; Conrad and Jones, 1929). Children continued to improve with advancing age, but the yearly increments became smaller as higher ages were reached. Whether the increments were due to improvement in memory per se or to such other variables as increased powers of observation, attention, or language facility it is difficult to say.

Recognition Memory. Another method common to the study of memory processes is recognition of familiar objects placed in a strange context. As might be expected, this is easier than recall, for the subject has all the items before him and needs only to identify them. Studies of recognition as a function of age are rare, however. Baldwin and Stecher (1924) made 5-sec. exposures of pictures which were then randomly mixed with strange pictures. Children aged 2, 3, 4, 5, and 6 years were able to identify the earlier exposures with an accuracy of 1½, 4, 8, 11, and 11 pictures respectively. Achilles (1920) found an age increase in recognition of seen words mixed with new words in children aged 8½ to 11½ years.

Forgetting. Forgetting is the negative aspect of remembering. Since the classic work of Ebbinghaus (1885), considerable research has been done on forgetting and on the variables concerned (see McGeoch, 1945). As we all know, forgetting is rapid at first and slower after a time, the rate depending on the nature of the materials learned, the degree of overlearning, the way in which the original learning occurred, and other such variables. The chronological age of the subjects seems to have little effect on the rate of forgetting, however.

One such study of the ability to retain poetry and nonsense syllables was conducted by Radossawljewitsch (1907), who tested children aged 7 to 13 years as well as a number of adults. At intervals of 5 min. to 2 months after learning the task, tests were given to determine the amount forgotten. No consistent age differences were found.

Another approach was taken by Lahey (1937), who investigated the relationship between *retroactive inhibition* and chronological age. Retroactive inhibition refers to the adverse or disturbing effect of material interpolated between learning and a test of recall. Lahey noted that retroactive inhibition tended to decrease with age (8 to 16 years), that is, older children were less easily disturbed by the interpolated material than were younger children.

Reminiscence. We might expect retention of material to be high directly after learning but that more and more will be forgotten as time goes by. This is not always true. Occasionally we find that memory of learned material improves with time. As has already been observed, this phenomenon is known as reminiscence.

Research on reminiscence began with the work of Ballard (1913), who made an extensive study of over 5,000 subjects aged 6 to 21 years. These subjects were required to memorize lists of nonsense syllables and poetry but were given insufficient time to learn the lists thoroughly. Daily tests were then given for 7 days. It was found that 6-year-olds improved over the first few days. On the third day, for example, the scores were 60 per cent higher than directly after the learning. After the third day, scores decreased. The most interesting finding was that the percentage of indi-

viduals who exhibited the reminiscence phenomenon decreased with age: 90 per cent of the 6-year-olds, 75 per cent of the 12-year-olds, and only 30 per cent of the adults showed this improvement with lapse of time. It appeared that most adults learned all they were going to learn immediately.

Ballard's findings stimulated considerable research in this area, and reminiscence was demonstrated for several kinds of learning tasks. Not all of Ballard's findings were corroborated, however, for more recent research has indicated that the phenomenon is about equally common in children and adults (see Munn, 1946).

SYMBOLIC PROCESSES

Except for language, we have so far been concerned only with the learning of fairly simple tasks. Now we come to complex learning, mediated by symbolic processes. According to Munn (1938), symbolic processes may be considered as representative processes standing for objects, situations, or events experienced in the past. They are implicit, or inner, activities of the organism, and their existence can therefore be inferred only from overt behavior. Perhaps the simplest example is the delayed-reaction test mentioned earlier. Here, a problem may be solved only if the subject can recall what happened several seconds, minutes, or days earlier.

Much of the insightful kind of learning may be of symbolic nature involving rapid implicit manipulation of various environmental features. Although symbolic processes may play a role in solving mazes or problem boxes, they are more clearly evident in such activities as imagining, thinking, reasoning, and forming concepts. These topics, frequently excluded from the area of learning, will be included here, since they do involve some kind of manipulation of learned materials and generally result in further learning.

Imagination. Imagination plays an important part in the child's mental life. Through imaginative activities he can transcend the boundaries of space and time, deal with obstacles, and visit strange places. To the small child, the "bear" at the corner is a very real bear; fairies and elves are real people; and the gauze-costumed, tinsel-winged angel of the Christmas pantomime is a very real angel. Imagination and make-believe activities are important to both emotional and social development. Through them, frustrations of the adult world are reduced; through them, children gain experience in the give-and-take essential to social intercourse.

Various tests have been devised to explore children's imaginative activities. Clues are offered by drawings, paintings, responses to pictures, reactions to toys, and the structures that the young child builds with his blocks. Clinicians have known this for many years. The Rorschach, or ink-blot, test, for example, is a current favorite in appraising fertility of

imagination in terms of the number of objects suggested by each ink blot. Story techniques have given rise to the Thematic Apperception Test. Play therapy is based on the disturbed child's reactions to toys and to play situations.

It is difficult to estimate just when the child begins to imagine. According to Jersild (1947), some children are capable of quite complicated imaginative activity before they are able to speak. With the acquisition of language, prehension, and locomotion, however, imaginative activities become more noticeable to the observer, and investigations usually begin from that point. Burnham (1940) reported that 1.5 per cent of the remarks of 2-year-olds were imaginative as compared with 8.7 per cent of the 4-year-old's comments. This increase continues through the preschool period. Markey (1935), who watched the number of imaginative situations devised by children playing with dolls and kitchen furniture, noted a sixfold increase between the ages of $2\frac{1}{2}$ and 4 years. The younger children based their imaginative play on the specific objects available. The activities of the older groups not only were more complex but also involved various themes and objects outside the immediate setting.

An extremely large group of 2,642 boys and 2,138 girls ranging in age from 9 to 18 years was studied by Valentiner (1916). He related the beginning of a story and gave hints regarding themes which the subjects were asked to finish. The story and directions follow:

This is the beginning of a story about the moon:

"On a recent night," narrated the moon, "I was sliding through heavy clouds of snow. My beams tried to pierce them in order to see what was happening on earth. Finally, the clouds parted before me and . . . ." You finish the story. You may choose any one of the five themes suggested below:

1. The moon sees a shipwreck.
2. The moon has a conversation with the giant, Roland, at the town hall of Bremen.
3. The moon comforts a sick man who is lying in bed.
4. The moon tells about a camp of hikers in the neighborhood of Bremen.
5. The moon talks with a pupil who cannot prepare his lessons.

There were three main differences between the themes of adolescents and those of children. First, the adolescents described the moon's feelings, emotions, and thoughts, while the children described the moon as an acting being. Secondly, while the children clung closely to the main theme, the adolescents enlivened their stories by various side incidents and happenings. Thirdly, the children's style was naked and devoid of the artistic touches and embellishments which characterized the adolescents' stories. Girls of all ages showed more imagination than boys.

Thinking and Reasoning. Munn (1938) has given us a good working definition of thinking. He considers it a "form of activity in which the organism, instead of manipulating the objects and situations of its environment, manipulates their surrogates or symbols." Under this broad definition we may subsume such activities as reveries, fantasies and daydreams, and recalling aspects of past experiences as well as reasoning. Reveries involve manipulating symbols in a haphazard or undirected manner; reasoning, on the other hand, is closer to reality and depends on manipulating symbols directed toward a certain end—the solution of a problem. Since reasoning is the most important kind of thinking, it is of primary interest here. Much research has been done in this area, but we shall deal especially with (1) its initial appearance and (2) age changes in reasoning ability.

Piaget's Work on Thinking. We have already mentioned Piaget's ideas concerning the egocentricity of children's speech. According to Piaget (1928, 1930), children's thought processes differ qualitatively from those of adults and are characterized not only by egocentrism but also by *syncretism* and *transduction*.

We have already explained Piaget's use of the term egocentrism. By syncretism, he means that children tend to combine incompatible ideas into a single impression. Thus, in answer to the question, "Why doesn't the sun fall down?" the child may say, "Because it is high in the sky," or "Because it is hot." Transduction refers to the child's tendency to base whatever generalization he is capable of on a single case. Piaget believes that a child is incapable of adopting another's point of view until around the age of 12, at which time he is able to generalize and to draw logical conclusions.

As stated earlier, Piaget's ideas prompted much research. Most of the ensuing work has failed to support his theses. Hazlitt (1930) and Abel (1932), for example, demonstrated that adults, confronted with unfamiliar problems, gave answers quite as self-contradictory, inconsistent, and naïve as children. Oakes (1945) noted that adults use about as much syncretic reasoning and give as many egocentric responses as children. Common observation alone indicates that adults frequently generalize on the basis of a single case, are often inconsistent in their arguments, and frequently disregard others' viewpoints and opinions.

Reasoning during Preschool Years. Numerous studies have probed children's reasoning ability. Several of them employed techniques modified from "reasoning" tests used for animals (Maier, 1936; Gellermann, 1931). An example may be found in the double-alternation maze originally used by Hunter to study reasoning in rats and raccoons. The essentials of this maze are shown in Fig. 73. It is a bilaterally symmetrical structure with a central alley down which the child walks to reach a choice point X,

where he must turn either right or left. Once the correct turn is made, the child passes through an unlocked door, eventually returning to point X. If an incorrect turn is made, he finds the door locked and is forced to revert to the choice point and to turn in the opposite direction.

The problem confronting Gellermann's subjects was to learn a RRLL sequence of turns from choice point X. Since the choice point remained constant, subjects could not make use of any differential stimuli but had to "figure out" the correct sequence. No children under the age of 5 years were able to do this. From 5 to 13, the number of trials and errors decreased with age. College students were much superior to the children, solving the problems in 6.2 trials as compared with 15.4 for the younger group. When subjects were asked how they solved the problem, they indi-
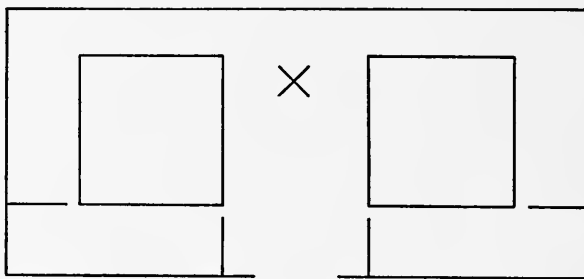
FIG. 73. A double-alternation maze. (*From Munn, N. L. Learning in children. In L. Carmichael (Ed.), Manual of child psychology. New York: Wiley, 1946. P. 432. By permission of the publishers.*)

cated that verbalization played an increasingly important role. Thus, thinking or repeating "two turns to the right and then two turns to the left" facilitated the solution.

Using other techniques, other investigators have reported essentially similar findings (*e.g.,* Heidbreder, 1927, 1928). Roberts (1932) demonstrated that children were able to discover a principle at 2 years but were unable to express it or to apply it to other situations until the age of 3. Ability to generalize increased with age. The kind of reasoning involved in more complex problems seemed to be lacking until the sixth year. It may therefore be concluded that earliest signs of reasoning appear around the third year and increase thereafter.

Reasoning during Later Childhood and Adolescence. Reasoning ability continues to develop throughout childhood and the teens. The tests which have been tried by older children are chiefly of a paper-and-pencil variety, in which subjects are required to solve problems in logic, detect absurdities in statements, etc.

A series of 50 reasoning tests was devised by Burt (1919) for English children aged 7 to 14. These were designed to test inductive-reasoning

ability (*i.e.*, from particular to general) and to appraise the ability to solve problems involving the successive elimination of various untenable hypotheses. The following are examples:

At age 7, children can solve simple problems like this:

Test No. 1. Tom runs faster than Jim. Jack runs slower than Jim. Who is the slowest, Jim or Jack or Tom?

At age 8, children can eliminate untenable hypotheses:

Test No. 8. I don't like sea voyages and I don't like the seaside. I must spend Easter either in France or among the Scottish hills or on the south coast. Which shall it be?

At age 13, children can solve problems involving the discovery of a general rule derived from a number of particular instances:

Test No. 40. One pound of meat should roast half an hour; two pounds, three-quarters of an hour; three pounds, one hour; eight pounds, two and a quarter hours; nine pounds, two and a half hours. From this can you discover a simple rule by which you can tell from the weight of a joint how long it should roast?

The number of graded reasoning tests which children could solve at different ages from 7 to 14 years is illustrated by Fig. 74.
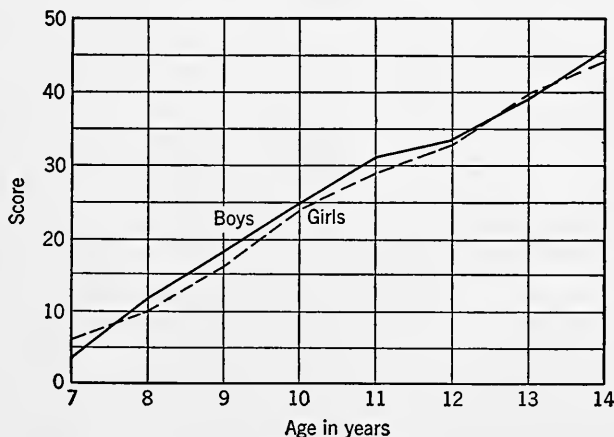
FIG. 74. Development of reasoning. (*From Burt, C. The development of reasoning in children. J. exp. Pedagogy,* 1919, **5**, 68–77, 121–127.)

In another investigation, 200 children aged 6 to 12 were compared with college students for ability to solve problems in logic (Moore, 1929). These problems were of three types. The first type involved verbal reasoning, for example, "If all fish in the world have gills, can I be sure that the fish in Alaska have gills? Why?" The answer, which calls for a specific conclu-

sion based on a generalization, was given by a majority of the youngest children in the group. The second type consisted of statements of autistic fallacies, such as, "If one washes, he cleanses himself from dirt; if one sins, he is dirty; if one washes, he cleanses himself of sin. Why?" Children below 8 years were unable to understand or to refute this kind of proposition. The third variety involved logical fallacies, for example, "All automobiles have four wheels; this vehicle has four wheels; therefore it is an automobile. Why?" Again some of the youngest children were able to discern fallacies and to tell why the conclusions were untrue. Table 14

TABLE 14. DEVELOPMENT OF LOGICAL-REASONING ABILITY AS A FUNCTION OF AGE*

Type of test	Age, years							
	6	7	8	9	10	11	12	College freshmen
Verbal reasoning..	23.1	24.8	32.1	43.1	51.1	56.0	63.2	88.0
Autistic fallacies..	0	0	1.25	4.0	3.05	14.2	23.1	83.0
Logical fallacies...	5.8	9.6	21.9	27.3	36.0	53.7	54.8	80.0

* Based on Moore, I. V. *The reasoning ability of children in the first years of school life.* Baltimore: Williams & Wilkins, 1929. Figures are in terms of per cent of maximum possible score.

records the gradual improvement in reasoning ability measured by the three types of tests. Note the improvement right through college level.

Detecting Absurdities. Ability to detect absurdities requires reasoning. Burt (1921) prepared a short story which contained many absurdities and gave it as a test to English children aged 8 to 14 years. A paragraph from this story follows:

A clean-shaven young Englishman of about fifty years of age stepped lightly from one of the first-class carriages and hurried slowly down the platform with both hands in his pockets, carrying a heavy bag, and gaily curling the tips of his moustache. His strange voice suggested that he was a native of Germany, born and bred, no doubt, in Paris, and by his dusty shoes I gathered he had walked over from New York that very morning.

In this test, the score was the number of absurdities detected at the various age levels. Burt found a gradual increase in scores with advancing age, ranging from 9 absurdities at the age of 8 to 14 at 11 years and 21 at 14 years.

The Terman-Merrill revision of the Stanford-Binet intelligence test contains items requiring detection of similar absurdities. Here is one of

the test items at the 10-year level: "A man wished to dig a hole in which to bury some rubbish, but could not decide what to do with the dirt from the hole. A friend suggested that he dig a hole large enough to hold the dirt, too."

Concept Formation. Concept formation is one of the most important of our learned activities, for concepts play a vital role in both thinking and reasoning. A concept may be said to have been "acquired" when the subject treats various objects, ideas, or events as belonging to a class and makes equivalent or nearly equivalent responses to all members of that class. Many of the words in our language are concepts.

Let us illustrate concept formation, using the word "apple." During the course of exploring his environment, a child sees the objects shown in Fig. 75. Through such experiences as looking, touching, smelling, and tasting, he notes that certain of these objects have similar shapes, feel, smell, taste, and so on. Consequently, after a time, he begins to group some objects and to exclude others. Selection of the common features of objects which are superficially similar in some respects and different in others is greatly facilitated by hearing family members designate only certain objects as "apples." While this is in progress, the child is rewarded if he uses the word "apple" with reference to some objects but not to others. Thus, through the media of direct experience, use of language, and reward and nonreward, he soon learns that "apple" refers to a class of items characterized by certain common features of shape, smell, and taste. At this stage, he is likely to think of the common features whenever he hears the word "apple."

In the same way, he learns the concept "chair" by dealing extensively with furniture and eventually by noting that all items referred to by this name have seats, legs, and a back. The concept of triangularity develops similarly through dealing with triangles differing in size, shape, position, etc., and noting that all are closed figures with three vertexes. It must not be supposed that such differentiation and grouping are either conscious or deliberate. Concept formation generally occurs at a nonconscious level.

These few examples illustrate quite simple concepts. As time goes on more complex ones are learned. Much of our formal education consists of learning the meaning and correct usage of such concepts as energy, velocity, gravity, etc. Specialized fields of knowledge have their own peculiar lists of basic concepts. If we examine intelligence tests, we note that considerable weight is given to the number of concepts used correctly by the individual, for they increase his efficiency in thinking, communicating, and solving problems. Some of the most generalized concepts developed by man are the symbols of higher mathematics, representing a great variety of conditions or operations which form the basis of new derivatives.

Perhaps the main factor responsible for man's superiority over other animals is the relative ease with which he can learn new concepts and manipulate them in thought processes. This has been well expressed by Ruch (1948), who points out that "it may certainly be said that the most profound psychological differences between man and the lower animals lies in the number, complexity and subtlety of the abstract concepts which man can acquire, and in the complex thinking which these concepts help to make possible." Although mammals such as rats and monkeys have learned such concepts as triangularity, they have accomplished it only with great difficulty and after prolonged training (Fields, 1932; Neet, 1933).

Some Genetic Studies of Concept Formation. Literature on concept formation in children is extensive. For our purposes, however, it will be
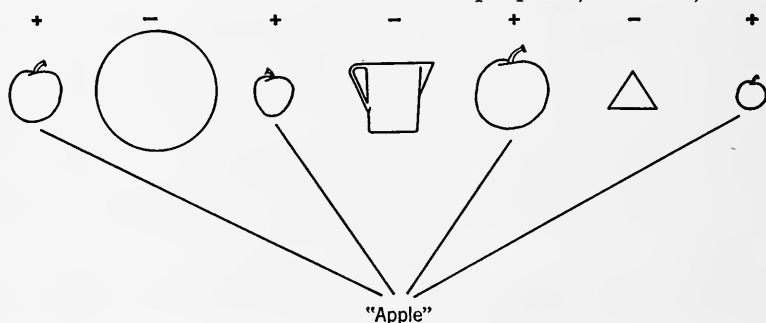
FIG. 75. Diagrammatic representation of concept formation. (*From Johnson, D. M. Essentials of psychology. New York: McGraw-Hill, 1948. P. 178. By permission of the publishers.*)

sufficient to discuss a few representative studies, especially those concerned with genetic development (for a fuller treatment of concept formation see Thompson, 1952).

Triangularity. The concept of triangularity has received considerable attention. Munn and Steining (1931) demonstrated that an infant as young as 15 months could discriminate triangularity. Gellermann (1933), who studied 2-year-old infants, also found that they could discriminate triangles regardless of size, position, and background. Children were superior to chimpanzees at this task.

Concept of Size. The development of the concept of "middle-sizedness" in children aged 2 to 5 years was explored by Hicks and Stewart (1930). Children were given three boxes differing in size and were asked to point to the middle-sized box. After learning the correct choice, the subjects were presented with a new trio of boxes and were requested to perform a similar task. This was repeated with another series. Only 1 out of 10 2-year-olds succeeded in developing the concept of "middle-sizedness." From the age of 3 years, the subjects grasped the meaning quickly and applied it to

subsequent series. With advancing age, the number of trials and errors decreased.

In another study, Thrum (1935) found that the concepts of "biggest" and "middle-sized" were quite well developed in 3-year-old children. Accuracy was greatest for the concept "biggest," less for "littlest," and least for "middle-sized."

Number Concepts. In our society, where so much stress is placed on measurement and on activities involving arithmetic, number concepts are especially important. Age norms have been provided by Terman and Merrill (1937). According to these norms, the number concept "two" should
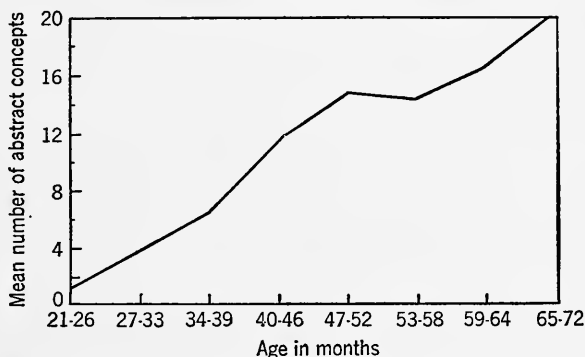
FIG. 76. Growth of abstract concepts as a function of age. (*From Welch, L. The genetic development of the associational structures of abstract thinking. J. genet. Psychol.,* 1940, **56**, 184. *By permission of the Journal Press.*)

be mastered by 4-year-olds; the concept "three," at 5 years; and the concept "nine," by the seventh year. Children use such words as "hundred" or "million" quite early, but close questioning generally reveals that they mean "many" or "a lot." The larger numbers begin to have meaning only when the child is well advanced in school and in arithmetic.

Time Concepts. Time concepts emerge slowly. The spontaneous verbalizations concerning time in children aged 1½ to 4 years were analyzed by Ames (1946). According to this study, corroborated by other data, children refer to the present before they refer to the future, and to the future before the past. The word "today" was used meaningfully around the end of the second year; the word "tomorrow," at 30 months; and "yesterday," at 36 months. Furthermore, 4-year-olds could tell morning from afternoon, 5-year-olds could name the day of the week, 7-year-olds could tell the seasons, and 8-year-olds could name the day of the month.

From a study of school children, Friedman (1944) concluded that, by the time they reach the sixth grade, children have a good fundamental knowledge of "our conventional time system." Undoubtedly this relates to the fact that number concepts are well developed by that age.

Development of Higher-order Concepts. Welch (1940) presented some important data on the hierarchical development of concepts (genus-species). Children aged 21 to 72 months were given pictorial and toy representations of such things as cows, pigs, horses, tables, chairs, oranges, and bananas and were asked to select the animals, fruits, vegetables, and other group concepts. Ability to do so credited them with knowledge of first-order abstract concepts. Next they were tested for more inclusive groupings such as "foods" comprised of both fruits and vegetables. Credit for second-order concepts was based on success in this task. Figure 76 indicates that the mean number of abstract concepts gradually increases from a low of 1 at the age of 2 years to 20 at the age of 6 years. Unfortunately, we have no data beyond this age range. We would probably not be wrong in assuming that higher orders emerge with advancing age, however, for it is well known that some of the scientific disciplines employ concept hierarchies of the eighth or ninth orders.

LATER-AGE CHANGES IN LEARNING AND SYMBOLIC PROCESSES

Literature on later-age changes in learning and remembering is quite extensive. Since Ruch (1933) has given an excellent summary of the early studies, we shall mention only the more important of this pioneer group and supplement them with more recent investigations. Research on later-age changes in symbolic processes such as imagination, reasoning, and concept formation is, on the other hand, very scarce.

Learning Ability

Various investigators have demonstrated that as old age approaches many tasks become more and more difficult to learn. The ease or difficulty appears to depend on the nature of the material in question, however.

Thorndike's Work. Perhaps the classic study on learning in old age is that of Thorndike *et al.* (1928). Thorndike worked with well over 2,000 subjects from 20 to 60 years whom he classified according to three age levels: 20 to 24 years, 25 to 34, and over 35 (mean age, 42 years). Backgrounds of these subjects varied all the way from university to Sing Sing prison.

The subjects were required to learn various tasks ranging from the simple one of drawing a line of specified length to complex university subjects. Table 15 shows the learning tasks assigned and also the achievements of the oldest group as compared with those of the youngest. In general, the older subjects were inferior to the younger, although the age decrement was highly dependent on the learning task. Such tasks as drawing a line of prescribed length while blindfolded, learning a code,

and associating numbers with nonsense syllables showed the greatest deterioration.

TABLE 15. AGE DIFFERENCES IN ABILITY TO LEARN*

Material to Be Learned	Performance of Oldest Group Relative to Youngest, Per Cent
Learning a letter code.................................	61
Drawing lines of prescribed length (blindfolded)...........	64
Associating numbers with nonsense syllables..............	64
Learning to write with wrong hand......................	72
Learning an artificial language (Esperanto)..............	79
Substitution of letters in words.........................	81
Elementary-school studies..............................	88
Typewriting...	About 95
Practice in addition....................................	96
Learning stenographic symbols.........................	About 100
University studies.....................................	Over 100

* Based on data from Thorndike, E. L. *Adult learning.* New York: Macmillan, 1928.

Thorndike believes that these tests measure the "sheer modifiability" of the organism, since they are minimally dependent on previously acquired abilities and past learning of content matter. On the other hand, he affirms that such tasks as typewriting, addition, and school and university studies are accomplished just as well or even better by older subjects because they are tasks upon which subjects can bring to bear their store of knowledge and in which they are more interested. One wonders whether much of the decrease in performance on Thorndike's tests of "sheer modifiability" may not be due to lack of interest. Certainly, drawing lines hundreds of times or dealing with nonsense material offers little challenge to older subjects. However, Thorndike concludes that there is an over-all deterioration approximating 20 per cent in learning ability during the 20-year period from 22 to 42 years of age, or roughly 1 per cent per year (see Fig. 77).

Ruch's Work. Thorndike's work on the concept of modifiability was extended by Ruch (1934) to include senescents. Three groups of 40 subjects each—ages 12 to 17, 34 to 59, and 60 to 82 years—were given five learning tasks whose nature varied in *"the amount of reorganization of preexisting habit patterns required in learning"* (italics added).

Of the two motor tasks in this battery, one required the learning of a simple pursuit of a moving object, while the second demanded similar learning except that the subjects had to watch movements in a mirror. This second motor task therefore involved the reorganization of past habits. The three other tasks were verbal. The first involved the learning of pairs of meaningful words, logically related (horse, sheep; man, boy). The sec-

ond consisted of nonsense materials $(A \times M = B; E \times Z = G)$. The third required learning of false products $(3 \times 5 = 25)$. Accordingly, these three verbal tasks represented either the use of old verbal habits, the formation of new ones, or the overcoming of previously acquired habits.

The oldest group gave inferior performance on all five tasks. However, impairment was greatest on those tasks which involved interference or conflict with old habit patterns and considerable reorganization of old patterns prior to new learning. For example, the motor task requiring mirror vision showed greater decline than the same task with normal vision. Similarly, older subjects evidenced greater impairment in learning false products than in learning either nonsense materials or meaningful asso-
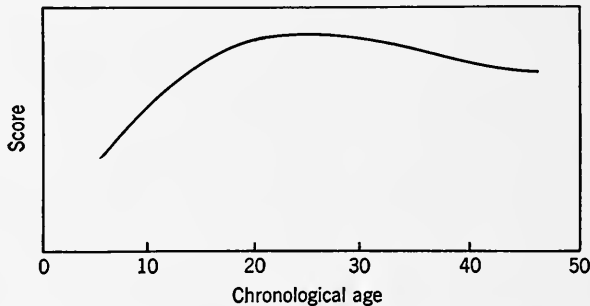
FIG. 77. An "ideal" curve for learning ability as a function of age. Thorndike drew this curve after testing many people of different ages on a large number of learning tasks. (*From Thorndike, E. L., et al. Adult learning. New York: Macmillan, 1928. P. 127. By permission of the publishers.*)

ciates. Nonsense syllables, in turn, showed greater deterioration than meaningful materials. The middle-aged group (aged 34 to 59) exhibited deficit patterns similar to the aged, but the decline was less. These findings agree with everyday observations that old people find it difficult to alter their habits and routines.

Welford's Study. Some valuable data on age changes in two types of sensorimotor learning have been reported by Welford (1951). A group of 50 subjects aged 20 to 69 years were tested on an apparatus consisting of a box containing a row of 10 Morse keys, each placed in front of an electric-light bulb. The bulbs and keys were so connected that, when a bulb flashed on, pressing a certain key would extinguish it and at the same time light another bulb. This, in turn, could be extinguished by pressing another key, and so on. The subjects were required to learn a series of keys which would produce a certain sequence of changes in lighting. Considerable care was taken to equate such variables as occupation and general background of subjects in the various age groups. All subjects were interested in the problem.

The learning scores for the five decades represented are shown in Fig. 78. Subjects in the three decades from 20 to 49 years required approximately the same time and number of trials and made approximately the same number of errors in learning the problem. Beyond this age range, however, all scores climbed rapidly until subjects in their 60's needed more than twice the number of trials, made roughly 3½ times the number of errors, and required about four times as long as subjects in their 20's. As with many other tasks, variability increased with age.
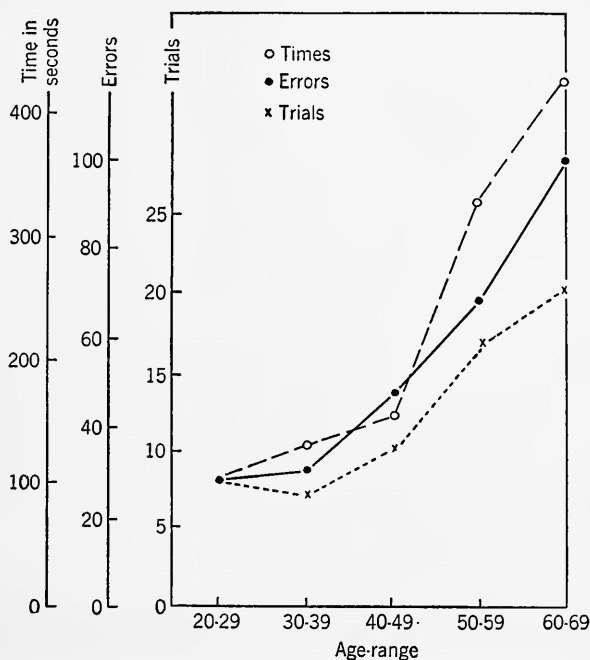
FIG. 78. Age changes in the learning of a motor task. (*From Welford, A. T. Skill and age. New York: Oxford, 1951. P. 113. By permission of the publishers.*)

The age decrement in learning was accompanied by decreased retention of what had been learned. Of 10 subjects in their 20's, 8 were able to reproduce the series correctly on the first recall test; not 1 out of 20 subjects aged 50 to 69 years was able to do so. Some interesting qualitative differences in the manner in which the different age groups approached the learning problem were noted:

Those in their twenties seemed to approach the learning task without any very clear idea of what they were going to do, and allowed the task itself to dictate their method. The subjects in the thirties and forties were more circumspect, carefully examining the lights and keys before beginning their first trial. They asked questions about the method of learning they should adopt, often of a de-

ductive nature . . . the approach of the subjects in their fifties and sixties was
. . . much more varied. Some showed the same characteristics as subjects in
their thirties and forties, and when examining the apparatus were clearly trying
to evolve a technique. Others, however, seemed to have difficulty in understand-
ing the task [pp. 115–116].

The second motor task given by Welford in this series was more com-
plex. It consisted of a number of problems in electricity in which subjects
had to find which terminals of the electric apparatus corresponded to
terminals noted on a circuit diagram. This could be accomplished by
taking readings on a resistance meter. The problem was a serial one in
which readings would enable the subjects to identify one or two of the
easiest terminals readily. This information was then used as a guide for
further reading, which in turn identified another terminal, and so on.
Careful precautions had been taken to ensure that none of the subjects
had any previous knowledge of electrical or radio work.

Two groups of subjects whose average ages were 20.1 and 45.9 years
were tested. Results demonstrated that the older subjects were just as
accurate in their solutions as the younger group. The older subjects
required much more time, however—about half again as much as the
younger people. Welford concludes that the additional time required by
older subjects indicates that they find it difficult to give meaning to the
readings and that the greater number of readings shows that they forget
and thus have to reread a number of times. Several older subjects com-
plained that they "could not hold the readings in their heads."

Remembering

It is popularly believed that the ability to remember diminishes with
age. We often hear older people say, "I'm becoming forgetful," "My
memory's failing," or "I can't seem to remember any more." Experi-
mental literature confirms this to a degree. However, research indicates
that the magnitude of deterioration, like that of learning, depends on
the nature of the material concerned.

Gilbert's Study. Perhaps this is best illustrated in a study by Gilbert
(1941), in which 11 different memory tests were given to 174 subjects
aged 20 to 29 and to another 174 subjects between 60 and 69 years of age.
The two groups were individually matched on a basis of vocabulary
scores. The tests as well as the results are shown in Table 16. According
to these data, older subjects were inferior to younger ones in all 11 mem-
ory tests. Magnitude of memory loss varied from 8.5 to 60.4 per cent,
depending on the nature of the material. Simple material of a repetitive
nature such as visual and auditory digit spans showed slight decline
(approximately 10 per cent), but, as the repetitive tasks increased in

difficulty, impairment also increased. This is well illustrated by the reversed digit span (21.2 per cent), in which subjects must reverse old habit sequences. Again, when subjects had to retain more complex ideas, such as several ideas of a paragraph or a complex design, the loss rose to a 40 per cent level. Finally, material which is not only complex but also entirely unfamiliar, such as a Turkish-English vocabulary, showed the greatest decrement of all.

A further important finding was that the "brightest" of the old subjects evidenced less deterioration both relatively and absolutely on all tests. When compared with comparably intelligent young people, they showed a mean loss of only 20 per cent as against 35.5 for the total older

TABLE 16. PERCENTAGE OF LOSS IN OLDER SUBJECTS (60–69) ON VARIOUS MEMORY TESTS*

Material to Be Remembered	Loss
Visual memory span for digits	8.5
Auditory memory span for digits	11.8
Reversed digit span	21.2
Sentence repetitions	21.3
Knox cubes	26.2
Retention of paragraph	39.7
Immediate memory of paragraph	41.8
Memory for designs	45.9
Retention of paired associates	54.6
Paired associates	58.7
Retention of Turkish-English vocabulary	60.4

* From Gilbert, J. G. Memory loss in senescence. *J. abnorm. soc. Psychol.*, 1941, **36**, 79. Quoted by permission.

group. Gilbert concluded that elderly subjects evidence relatively little decline in immediate memory for simple material but suffer greatly in ability to remember the new and unfamiliar.

Other Studies. Gilbert's findings are in large measure corroborated by Halstead (1943), who gave a battery of 25 short tests to a group of 20 seniles aged 68 to 83. He found least impairment on tests of rote memory (digits forward and short sentences), color naming, and simple arithmetic problems. Greatest impairment was evidenced in tests in which old habitual sequences had to be reversed (repeating digits or months backward), ideas reproduced from paragraphs just read, or details enumerated from a briefly viewed picture. Kubo (1938) also reported that rote memory declines little, at least in early senescence. He presented 355 healthy subjects aged 70 to 100 with lists of words of varying lengths, requesting them to reproduce the words after a period of study. His subjects evidenced no decline in rote memory until the age of 82, after which they deteriorated rapidly.

Changes in Memory throughout Life Span. The studies reviewed thus far have compared memory performance of older and younger subjects. Unfortunately, these studies do not indicate when memory impairment first appears. Several investigators have attempted to diagnose this by surveying most of the life span. One of the earliest reports is Willoughby's (1929). He tested 295 subjects ranging from 6 to 67 years. The tests involved ability to recall digit-symbol associations. According to his data, this ability increased until about 15 years and then declined gradually but steadily so that by the age of 60 performance had dropped back to the 6-year level.

A more extensive study of memorizing ability in 2,000 subjects is reported by Miles (1933). He observed a fairly gradual but persistent decline beginning around the age of 30. Recall of unfamiliar and difficult logical procedures showed the fastest deterioration.

Memory for Movies. How well subjects of different ages can recall events seen in movies was investigated by Jones *et al.* (1928). A group of 765 subjects aged 10 to 60, from a rural area in Vermont, saw three films (historical, western, and romantic). Immediately following presentation, they were given completion and multiple-choice questions covering the verbal and pictorial content of each film. The results of the analysis are graphically recorded in Fig. 79. The three curves are remarkably similar, showing improvement in recall up to the early 20's followed by a leveling off and eventual decline beyond the early 40's. The authors conclude that "the inferiority of the older group is not due to a speed handicap in performing the tests, nor to factors involving interest in the pictures, visual acuity or education."

"Old Recall" vs. "New Recall." Further data on age changes in memory are provided by Shakow *et al.* (1941) and Eysenck (1945). The former gave a group of 192 subjects, aged 15 to 90, two kinds of tests. The first kind was referred to as the "old-recall" group, consisting of personal information (*e.g.*, age, birthplace), current information (*e.g.*, how many feet are there in a yard?), alphabet, and naming of common objects (*e.g.*, spool, pencil). The second kind was referred to as the "new recall," involving sentence memory, forward and backward digit span, recognition memory (*i.e.*, recognition of pictures previously exposed and included in a group of unfamiliar pictures), memory for ideas (a 50-idea story), etc. The investigators found less deterioration on the tests involving old recall than new recall. Old recall showed little decline between ages 15 and 50 but a noticeable decrement after the fifth decade. New recall, on the other hand, began to decline at age 15.

Other sources provide additional evidence for the differential decline of memory for various materials. In a study of 84 seniles with a mean age of 75 years, Eysenck (1945) observed that there was least deterioration

for tasks involving a "mere reactivation of past experiences and knowl-edge." In standardizing his intelligence test for adults as well as in the Wechsler Memory Scale, Wechsler (1944, 1945) reported progressive deterioration of memory with increasing age but also called attention to differential decline (see Chapter 10).

Retroactive Inhibition. Another study on retroactive inhibition has a different approach (Cameron, 1943). When new material was interpolated between tests of learning and recall, much greater memory loss occurred
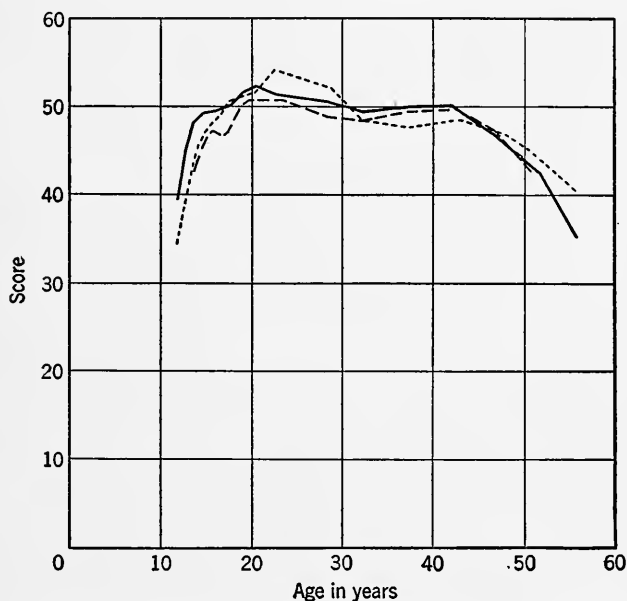
FIG. 79. Growth and decline in visual memory for motion pictures.——Test A (historical);------Test B (romantic);-- --Test C (western). (*From Jones, H. E., Conrad, H. S., and Horn, A. Psychological studies of motion pictures: II Observation and recall as a function of age. Univ. Calif. Publ. Psychol., 1928, 3, 233.*)

in older subjects than in young adult controls. The material to be learned in this instance consisted of a series of 3-digit numbers, while the inter-polated material was a 1-min. series of spelling words. With such simple material, no memory loss occurred in the older subjects in the absence of interpolated material, but a spelling period as short as 15 sec. was suffi-cient to produce memory loss in some cases. No such loss was noted in younger controls. Attempts were made to improve the memory of older subjects by increasing the oxygen supply to the brain through the inhala-tion of a high oxygen concentration. Various B-complex vitamins and insulin were also tried. No improvement resulted in either case.

Attempts to Improve Memory. Despite Cameron's failure to improve memory by artificial means, some success has recently been achieved in

this regard (Caldwell and Watson, 1952). Thirty females whose mean age was 75 years were divided into experimental and control groups. Members of the experimental group were given injections of sex hormones (estrogen and progesterone) controlled in such a way as to induce cyclic menstrual bleeding. Control subjects received injections of a neutral oil. All were given the Wechsler Memory Scale prior to treatment and were retested after 6 months of therapy. This memory scale consists of seven subtests which sample various aspects of visual and auditory memory. Administration of the scale was carefully controlled, and at no time did the psychologist in charge know which were experimental and which control subjects.

Examination of the controls' scores revealed a slight decrease after 6 months of oil injections. The experimental group, on the other hand, showed improvement in memory performance, significant at a .05 level of confidence. This is extremely interesting, because we might expect the slight drop evidenced by the controls since another 6 months had been added to age. Thus, the hormone therapy not only offset this expected drop but also increased performance above the initial level. While the increase was significant at only a .05 level of confidence, it is therefore quite possible that the increase added to the expected "normal" deterioration may have been highly significant.

Memory for paired associates (e.g., cabbage-pen) and for geometric design was especially improved. Such subtests as digit span and information showed no increased scores. Accordingly, it seems that hormone therapy was most beneficial in improving the memory tasks which show the greatest deterioration with age, and least or not at all beneficial for tests which show slight, if any, age decrements (see Table 16, page 265).

Symbolic Processes

Investigations of later-age changes in activities of a symbolic nature—that is, of critical thinking, reasoning, and imagination—are almost negligible.

Imagination. Of the rare available data on age changes in imagination, the most extensive were contributed by Miles (1934). Miles's sample included 1,203 subjects ranging from adolescence to senescence. Subjects were shown what Miles called a *kinephantom*—"a kind of animated inkblot or Rorschach figure"—consisting of a silhouette produced by a strip of material of a certain shape moving in a clockwise direction. According to Miles, persons with fertile imaginations will visualize this silhouette as moving in a counterclockwise direction, continuously fluttering, contracting and expanding, changing its route, and so on. Careful notes were made of the incidence and nature of movements seen by various age groups. Few, if any, age changes were noted. Miles concluded that "ap-

parently spontaneous imagination measured here has a quality of true agelessness."

Flexibility of Thinking. Several investigators have been concerned with age changes in various kinds of thinking. An interesting technique for measuring what he called "flexibility" of thinking was devised by Berg (1948). A group of young subjects of 17 to 28 years and an older group of 58 to 73 years were each given a pack of cards and asked to sort them into a number of piles. The cards could be sorted according to several criteria, for example, color, form, or number of figures, but the "correct" criterion was selected arbitrarily and was known only to the experimenter.

Initially, of course, subjects had to sort on a basis of chance. They were then told whether they were right or wrong. Whenever they managed to choose according to the right criterion, the category was changed without their knowledge. The measure of flexibility was the ability to detect these changes. Berg found that young subjects could shift readily but that not 1 of the 21 older subjects could progress beyond the first shift. The tendency to persevere in the original method was thus greater in older than in younger people.

Critical Thinking. Critical thinking throughout the life span has also received some attention (Watson and Glaser, 1943; Burton and Joel, 1945). The tests given have been designed to measure a number of abilities believed to be involved in critical thinking, among them the ability to generalize, to make inferences, to discriminate arguments, and to recognize assumptions. The joint findings of such investigations suggest that the ability to think critically improves with age until the middle 30's and subsequently declines.

Logical Thinking. An extremely interesting study has been reported by Welford (1951), whose work was mentioned earlier. This investigation concerns age changes in logical thinking. Each of Welford's subjects was given a number of statements among which certain interrelationships or inconsistencies existed, according to rules of logic. The subjects were required to point out fallacies and to draw deductions. The statements, which bore little resemblance to school materials, were of equal interest to all concerned and thus did not place the older subjects at any disadvantage. The mean age of the controls was 25 years; of the experimental group, 49 years. No time limits were set. Examples of the material follow:

Instructions: Read carefully the statements printed on the sheet and answer the questions following them.

Set B

    1. A right action is an action that will bring about at least as much good, or, failing that, will avoid at least as much evil as any other action open to the agent at the moment of acting.

2. A good man is a man who always does what seems to him, after due consideration, to be right.
3. It is always wrong to tell a lie or to break a promise.
4. Suffering in itself is undoubtedly evil.
5. In some cases it seems obvious that the only consequences of telling the truth or of keeping a promise will be to cause more suffering than would result from the opposite behavior.

Questions:
(i) Are these statements compatible with one another?
(ii) If not, what is the least number that must be rejected to yield a completely consistent set?
(iii) Write out such a list, containing the fewest possible rejections, and state briefly wherein lies the incompatibility between those you reject and those you retain.

It was found that the older subjects were just as capable as the younger ones of writing out some sort of answer, but the answers differed qualita-
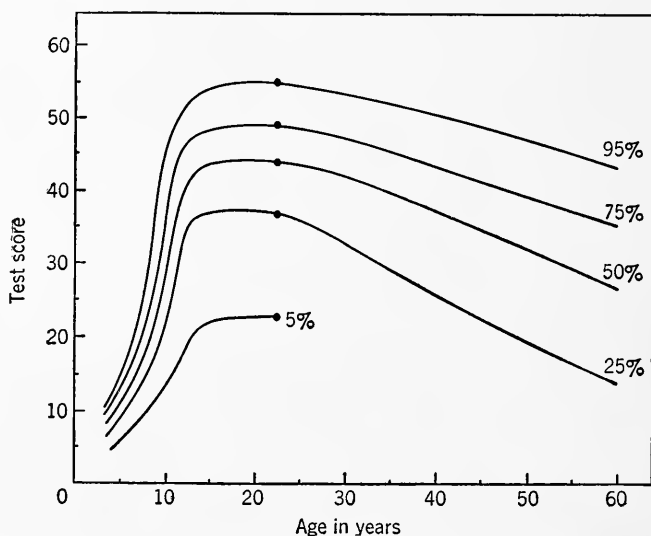
FIG. 80. Age changes in "capacity to understand and apply a fresh method of thinking" in subjects of below-normal, normal, and above-normal ability. (*From Raven, J. C. The comparative assessment of intellectual ability. Brit. J. Psychol.*, 1948, **39**, 16.)

tively. Welford states that "older subjects tended not to draw logical deductions based strictly on the statements as given, but to introduce supplementary premises or to confine themselves to comments upon the statements." The marked tendency merely to comment and to omit deductions appeared not to be caused by the older subjects' lack of interest, carelessness, misunderstanding of instructions, or differences in occupa-

tional background. Instead, according to Welford, the failure to make deductions is probably due to the failure of the central neural mechanisms concerned with organizing and interpreting incoming data.

One of the most extensive investigations of thinking is reported by Foulds and Raven (1948, 1949) in England. About 8,000 subjects of varied background, ranging in age from 6 to 60 years, were given the Progressive Matrices Test. This test consists of 60 problems whose solution demands comparisons, reasoning by analogy, and logical deductions. The investigators consider it a test of a person's "capacity to understand and to apply a fresh method of thinking."

The age changes in this capacity over most of the life span are illustrated by Fig. 80. As the graph indicates, the capacity increases during childhood to reach a maximum around the age of 15, remains stable into the middle 20's, and then declines. The rate of decline, however, depends on the subject's ability. For the brightest 5 per cent of the group (95th percentile), decline is slight; for the lowest 25 per cent, considerable deterioration is evident beginning around the mid-20's.

These findings are in line with the results of other investigators. Gilbert (1941), for example, observed that the brightest of her older subjects evidenced very little decline in various memory tasks (see also Chapter 10). This question of differential decline in performance in individuals of varying ability levels is of great social importance and merits further research.

INTELLECTUAL DEVELOPMENT

The last chapter was concerned with various tests used to appraise learning ability in man and lower animals. The studies that will be presented in this chapter are based on what are popularly known as "mental," or "intelligence," tests. They differ from the studies of the previous chapter in one main respect: they depend more on symbolic processes, and many of them involve considerable linguistic ability. There is no hard and fast boundary between learning ability and intelligence, however; indeed, some investigators consider them synonymous. The chapter divisions are therefore arbitrary.

Intellectual development is one of the most important of all aspects of human development, for its growth during the years of childhood and adolescence increases our sensitivity to environmental stimuli, enabling us to engage in more and more complex thought processes, to sense more refined meanings and relationships, and to solve more intricate problems—all of which help us to deal more effectively with the everyday world. In old age, the decline of intellectual powers decreases sensitivity and hence efficiency in coping with the environment.

This chapter will take up various ways of appraising intelligence, the well-known concept of IQ, and the many factors that influence intellectual performance. Finally, the course of development and decline of several mental abilities will be traced throughout the life span.

DEFINITIONS OF INTELLIGENCE

There is little agreement regarding a suitable definition of intelligence. The controversies need not concern us here, however, and we shall consider only a few examples from current literature. Munn (1938) defines intelligence as "the capacity for flexible adjustment." Goddard (1946) believes that it is "the degree of availability of one's experiences for the solution of immediate problems and the anticipation of future ones." While both of these definitions involve the idea of adjustment, others, like Terman's (1916), exclude this notion by calling intelligence "the ability to carry on abstract thinking."

Factors of Intelligence. Still others believe that intelligence cannot be appraised in terms of such general ability, because it consists of several factors which cannot be totaled. Thorndike (1926), for instance, thinks in terms of three levels of functioning: (1) abstract intelligence, (2) mechanical intelligence, and (3) social intelligence. For him, *abstract intelligence* is "the ability to understand and manage ideas and symbols such as words, numbers, chemical and physical formulae and the like"; *mechanical intelligence* is "the ability to learn, understand and manage things and mechanisms such as a knife, a gun, a mowing machine"; and *social intelligence* is "the ability to understand and manage men and women, boys and girls and to act wisely in human relations."

Thurstone (1946) does not believe in a "general" intelligence, either, and does not use this term but speaks instead of *primary mental abilities*, PMA. Using a complex statistical technique known as factor analysis, he has isolated 7 such primary abilities but believes that 12 are indicated. The 7 already isolated he calls S, spatial abilities; P, perceptual abilities; N, numerical abilities; V, verbal relations; M, memory; W, words (unrelated words as opposed to the V factor); and I, induction. He is fairly certain of two more which he tentatively calls R, reasoning, and D, deduction, but less certain of three as yet unnamed. Of these primary factors of intelligence he considers R and I most closely related to what has been called general intelligence and M most independent of other factors.

Wechsler's Definition. These are only a few of the many current conceptions of intelligence. For our purposes, however, a good working definition is offered by Wechsler (1944), who defines it as "the aggregate or global capacity of the individual to act purposefully, to think rationally and to deal effectively with his environment." He notes that intelligence "is global because it characterizes the individual's behavior as a whole; it is an aggregate because it is composed of elements or abilities which, though not entirely independent, are qualitatively differentiable."

Intelligence and Phylogenesis. Whether or not lower animals have intelligence depends on our definition of the concept. If we consider intelligence as the ability to think in abstract terms (Terman), then we must admit that we know little about animal intelligence; if we think of it as the ability to adjust to the environment, then common observation would indicate that animals are highly intelligent—perhaps more so than human beings; if we use the term synonymously with learning ability, then what was said about phylogenesis in Chapter 9 applies equally well here.

On comparing the learning abilities of the various phyla, Nissen (1951a) suggests a schema based on the sum total of attainments of animals at different levels of the phylogenetic scale. His schema is shown in Fig. 81. As he himself admits, this is a "rash venture." Nevertheless, it provides a tentative picture of how, during phylogenesis, animals have become able

to solve a greater variety of more complex problems. If we define intelligence in terms of ability to perform such tasks, then Fig. 81 offers an estimate of the intelligence of organisms at different levels of the phylogenetic scale.

MEASUREMENT OF INTELLIGENCE

All intelligence tests are based on the assumption that ability level is reflected in behavior and can therefore be measured indirectly by appraising various performances. This idea is not new. It is equally basic to an estimation of learning of the type discussed in Chapter 9 and to an evalua-
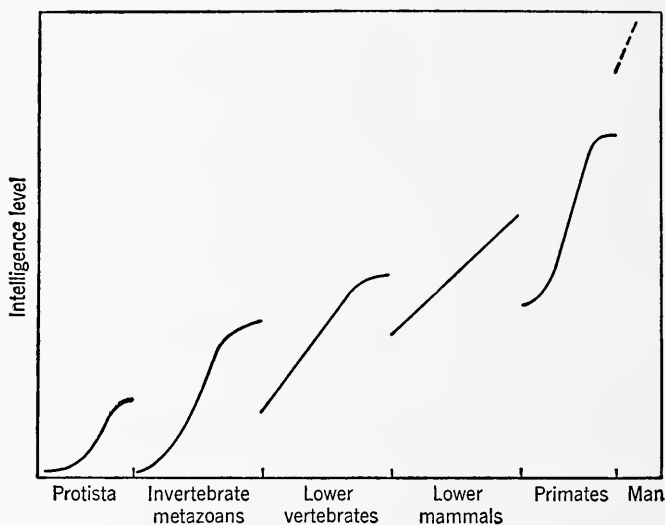
FIG. 81. A tentative estimate of comparative intelligence in the animal kindgom. Each of the curves represents an average, a pooling of attainments on a variety of problems. (*From Nissen, H. W. Phylogenetic comparison. In S. S. Stevens (Ed.), Handbook of experimental psychology. New York: Wiley, 1951. P. 382. By permission of the publishers.*)

tion of achievement in schools and colleges. A second assumption underlying intelligence testing is that, given equal opportunity, the brighter individual learns more from his everyday experiences and does better in problem solving than his duller contemporary. Thus, if two subjects have lived for the same length of time in similar environments, the brighter one will answer more questions correctly and will solve more problems of greater complexity in a shorter period of time.

Types of Intelligence Tests

A wide variety of intelligence tests are available. Some of them consist entirely of verbal material dealing with vocabulary, general information, analogies, etc.; others involve performance subtests requiring duplication

of block patterns, completion of jig-saw-type puzzles, and so on; still others combine both verbal and performance items. All tests have a common feature, however: to one degree or another they involve cultural experience. None of the many attempts to devise "culture-free" items has as yet succeeded.

Intelligence tests may be classified according to a number of criteria, for example, method of calculating the IQ, age group which they are designed to test, or nature of the items used. We shall follow the common and convenient dichotomy which depends on whether an individual or a group of subjects is tested at one time. Tests administered individually are time consuming; however, they provide the best appraisal available today. Group tests, on the other hand, have the advantage that they may be given to large numbers of subjects in limited time and are quickly and easily scored; to offset this, they are less reliable than the individual tests. Perhaps the most common of the individual tests are the Stanford-Binet and the Wechsler-Bellevue. Group tests include the Army Alpha and the Army Beta, the A.C.E. Psychological Examination, and many others (for more complete lists see Goodenough, 1949; Greene, 1952).

The Stanford-Binet, 1937 Revision. The Binet type of test dates back 50 years to the early efforts of Alfred Binet, founder of the psychological laboratory at the Sorbonne in Paris. As early as 1896 Binet and a colleague had published an article describing certain tests which they proposed to give to Paris school children. Interestingly, the 11 subtests described had much in common with current tests, but not all of them are considered measures of intelligence today. Binet's early battery included tests for (1) memory, (2) imagination, (3) mental imagery, (4) attention, (5) comprehension, (6) suggestibility, (7) aesthetic appreciation, (8) motor skill, (9) will power as evidenced by sustained effort in muscular tasks, (10) moral sentiments, and (11) judgment of visual space. A few years later, when Binet was requested by the Paris school board to devise some technique for discriminating between fast and slow learners, he had the advantage of this earlier experience with "mental" tests and a fairly clear idea of the essential factors in intelligence. "To judge well, to comprehend well, to reason well—these are the essentials of intelligence," said Binet.

The earliest Binet scale was published in 1905. It contained 30 items such as the following:

1. Visual coordination of hands and eyes.
2. Ability to grasp a cube placed in the palm.
8. Ability to find objects which the experimenter names in a picture.
12. Ability to tell which is the heavier of two weights.
15. Immediate memory for sentences of fifteen words.
27. Knowledge of what is the best thing to do in twenty-five situations of graded difficulty.

This was an era of tremendous interest in tests, and other psychologists immediately began to experiment with items like Binet's. The early Binet scale underwent several revisions. Today we use the 1937 revision by Terman and Merrill of Stanford University (hence the name Stanford-Binet). The items have been modified and arranged according to level of difficulty to suit the various age levels. A few examples follow:

Year II:
    1. Place three small blocks into similar holes in a board.
    4. Build a four-cube tower after demonstration.

Year VI:
    2. Make a simple bead-chain pattern from memory after demonstration.
    6. Draw a pencil through a sample maze to make the shortest path.

Year X:
    4. Give 2 reasons to support an oral statement.
    6. Repeat 6 digits after one oral presentation.

Average Adult:
    2. Transcribe a short message in a code which is exposed.
    3. Tell in what way verbal opposites are alike.

Superior Adult:
    2. Read aloud a problem concerning direction and distances traveled, and give answers without using paper and pencil.

As the scattered illustrations indicate, subtests for each age level include both verbal and performance tasks. However, one of the chief criticisms of the Stanford-Binet is that it becomes progressively more linguistic as the testee's age advances. Despite this, its two alternative forms, *L* and *M*, have for many years been the most valid, reliable, and widely used of all available intelligence tests for school-age children.

The Wechsler-Bellevue Scale. The Wechsler-Bellevue Scale was first used by Wechsler at Bellevue Hospital in 1939 but was not published until 1944. Like the Stanford-Binet, it is administered individually. It was originally designed for adults, but more recently the adult battery has been supplemented with another scale called the Children's Wechsler. At all age levels it is becoming increasingly popular.

The Wechsler adult scale consists of 11 subtests—5 verbal, 5 performance, and an alternative or optional verbal subtest to be used when necessary. Since so many of the studies which we are about to discuss refer to these subtests, we shall list all of them. The correlations between subtest scores and total scores for adult groups are indicated after each subtest.

A. **Verbal**

1. *Information:* 25 questions, 7 involving geographical location and distance, 3 authorship, 3 measures, 3 hard definitions, and 1 each in aviation, date, inventor, name of President, average height, population, etc. The difficulty range is large ($r = .66$).

2. *General comprehension:* 12 questions involving knowledge, judgment, and attitudes ($r = .66$).

3. *Arithmetical reasoning:* 10 problems to be done mentally, involving simple language, analysis of a problem, and computation ($r = .63$).

4. *Digits forward and backward:* The score is the longest span to be repeated correctly ($r = .51$).

5. *Verbal similarities:* 12 pairs of words for which one common aspect must be mentioned ($r = .73$).

B. **Performance**

6. *Picture completion:* 15 cards on which pictures of common objects lack essential parts. The examinee must tell what parts are missing ($r = .61$).

7. *Picture arrangements:* 6 series of cards similar to comic strips to be arranged in temporal sequence ($r = .51$).

8. *Object assembly:* 3 dissected pictures to be assembled like a jig-saw puzzle ($r = .41$ to $.51$).

9. *Block designs:* 7 designs to be duplicated from colored blocks ($r = .73$).

10. *Digit symbols:* Substituting symbols which correspond to given digits shown in a key ($r = .63$).

C. **Alternate verbal**

11. *Vocabulary:* 42 words ranging in difficulty, which examinee must explain or define ($r = .85$).

[Adapted from Greene, 1952, 122.]

Group Tests. A good example of group tests of the paper-and-pencil variety is the Army Alpha, which was first used in World War I. With more recent modifications, it is still in good standing. It is really a battery of eight subtests, most of which are rigidly timed:

1. Span of auditory attention: following increasingly complex verbal instructions.
2. Arithmetic problems: 5 minutes for 20 problems.
3. Common sense or practical judgment: 1.5 minutes for 16 items.
4. Synonyms and antonyms: 1.25 minutes for 40 pairs of words.
5. Rearranging confused sentences: 2 minutes for 24 sentences.
6. Completing number series: 3 minutes for 20 series.
7. Verbal analogies: 3 minutes for 40 analogies.
8. Checking multiple-choice items: 4 minutes for 40 items of miscellaneous information.

As we see, the Army Alpha (like the individual tests) contains a variety of tasks. These tasks, however, are all of a verbal nature and stress the time

element. Although many other intelligence tests are available, these few examples serve to illustrate the kinds of items used to rate over-all intelligence and to indicate that the various subtests may yield information regarding components of intelligence such as memory span, comprehension, reasoning, etc.

Power, Speed, and Breadth Tests. Intelligence tests may also be classified as power, speed, or breadth tests or a combination of all three. *Power tests* allow sufficient time for the examinee to try most or all of the items he can do so that the score becomes an indicator of his highest achievement. *Speed tests* are of two kinds: (1) the time-limit test, in which all items are of equal difficulty and in which the time given is so short that no one can finish, the score being the number of items completed; and (2) the work-limit test, in which the examinee is permitted to finish the standard set of operations, the time required to do so becoming his score. *Breadth tests* measure a wide range of skills or abilities; a good example is the general-information subtest of the Wechsler-Bellevue. It may be well to keep these three factors in mind—power, speed, and breadth—for we shall find that they do not deteriorate at the same rate in old age.

Determining the IQ

So far, we have merely given a few examples of intelligence tests. Let us now see how psychologists use these tests to determine the degree of brightness or dullness of the individual. A comparison of the performance of one person with others is clearly essential, since a score can be high or low only in relation to other scores.

Calculating the Intelligence Quotient (IQ). The ability index commonly known as the IQ can be explained most clearly through the concept of *mental* age (MA), first introduced by Binet in 1908. If a child's performance on the Stanford-Binet equals the performance of 12 year-old children, for example, he is said to have a mental age of 12 years; if it equals the performance of 14-year-olds, a mental age of 14 years, and so on. This tells nothing about relative ability, however, and to get a better estimate we must also know the chronological age. Thus, if the child is 10 years of age in calendar years but has a mental age of 14 years, we know that he is far brighter than the average child; if he is 14 years old chronologically and also has a mental age of 14, he has average ability; but if he is 15 or 16 years old and still has a mental age of 14, he is mentally retarded. Hence, we compare mental age with chronological age to determine relative brightness or dullness.

Some time after Binet had introduced the mental-age concept, the IQ was suggested as a more meaningful way of recording the ratio of mental age to chronological age. Like many improvements, it was simple in prin-

ciple. All that was necessary was to divide mental age by chronological age and multiply this fraction by 100 to get rid of the decimals, thus:

$$IQ = \frac{MA}{CA} \times 100$$

According to this formula, the child whose mental age is 10 years and whose chronological age is also 10 years will have an IQ of 100; if the mental age were 14 years, the IQ would be 140, or 40 IQ points above the average child; if the mental age were 8 years, his IQ would be 80, or 20 IQ points below the average ability level of other 10-year-old children.

It might clarify matters if we showed how an IQ is actually calculated in practice. Let us take the Stanford-Binet test. As we have seen, this test contains a number of tasks (usually six) at each age level. The MA is determined by the number of these tasks actually passed. Let us take the case of Bobby, who is 8 years, 2 months old. We shall assume that he can do all the items below the 8-year age level, 5 out of 6 items at the 8-year level, 3 items at the 9-year level, and 1 at the 10-year level. Each of these subtests, or items, represents 2 months of mental growth, since there are 12 months in a year and 6 items per year level. Thus, Bobby's record reads as follows:

All items below 8 years...................	84 months
5 items at 8-year level (5×2)...........	10 months
3 items at 9-year level (3×2)...........	6 months
1 item at 10-year level (1×2)...........	2 months
Total................................	102 months, or 8 years, 6 months

Since MA = 102 months and CA = 98 months, then

$$IQ = {}^{102}\!/_{98} \times 100 = 104$$

Bobby is thus of about average intelligence.

Unlike the Stanford-Binet, the Wechsler-Bellevue test does not make use of the concept of mental age. Wechsler considers the IQ merely "the place of the individual in a group of individuals of approximately the same age." Scores are therefore converted directly to IQ's by means of statistical tables; weighted scores of verbal and performance scales are combined to give an over-all quotient for the whole battery.

Distribution of Intelligence in General Population. It has been demonstrated that many biological characteristics such as height and weight are normally distributed throughout the population. This fact led investigators to anticipate that intelligence might be similarly distributed, and when the population was sampled it was found that IQ's fairly well approximated a normal distribution curve. The different IQ levels together

with the percentage of the population in each level are shown in Table 17. It can be seen that most people fall in the 90-to-110 IQ range with fewer and fewer falling in successive categories moving away from this "normal" range in either direction.

TABLE 17. COMPARISON OF CLASSIFICATIONS OF INTELLIGENCE ACCORDING TO THE STANFORD-BINET AND WECHSLER-BELLEVUE TESTS*

Stanford-Binet data			Wechsler-Bellevue data		
IQ	Classification	Per cent of population	IQ	Classification	Per cent of population
140 and over	Very superior	1.33	128 and over	Very superior	2.15
120–139	Superior	11.30	120–127	Superior	6.72
110–119	High average	18.10	111–119	Bright normal	16.13
90–109	Average	46.50	91–110	Average	50.00
80–89	Low average	14.50	80–90	Dull normal	16.13
70–79	Borderline defective	5.60	66–79	Borderline	6.72
69 and below	Mentally defective	2.63	65 and below	Defective	2.15
Total........	....	99.96	Total........	....	100.00

* Based on data from Terman, L. M., and Merrill, M. A. *Measuring intelligence.* Boston: Houghton Mifflin, 1937; and Wechsler, D. *Measurement of adult intelligence.* Baltimore: Williams & Wilkins, 1944.

Constancy of IQ. Once an IQ has been determined, it may well be asked how stable a measure this is. The constancy of the IQ has been widely disputed in the past. Extensive research has revealed that it depends on a number of factors such as IQ level, age of the testee, length of time between test and retest, etc. This will become clearer as several studies are examined.

In 1942, McNemar used the Stanford-Binet to appraise variability of IQ scores over a 2-week interval. He found that approximately two-thirds of the children retested were within 4 or 5 points of their original score, and only 5 per cent varied by more than 5 points. This picture represented the over-all group, however. When scores were analyzed according to age, it was observed that preschool children fluctuated much more than school-age children or adolescents. Moreover, children who deviated from the average IQ level changed more than the average child, and of these deviants, bright children changed more than dull children.

When tests and retests are given at intervals of several years, the IQ changes may be fairly large. This is well illustrated in a study by Cattell (1937), who reported that 0.3 per cent of the subjects studied changed 40

points or more according to Stanford-Binet tests; 1 per cent changed 30 points or over; 5 per cent, 20 points; 10 per cent, 15 points, and 25 per cent, 8 points or more.

Table 18 summarizes the relationships under discussion. Two things become evident immediately: (1) the longer the interval between tests, the greater the IQ change, and (2) children who deviate from the average are more prone to change than those in the normal range of intelligence. It will be noted that the median IQ change of normal children over a 6-year period is only a little over 1 point. On the other hand, children of superior intelligence (IQ of 130 to 139) changed 16 points in the same length of

TABLE 18. MEDIAN IQ CHANGES OVER VARIOUS PERIODS*

IQ level	Months between tests, 0–24		Months between tests, 36–72	
	N	Points changed	N	Points changed
140 and over	18	+8.5	0	
130–139	26	+1.5	13	+16.0
120–129	66	+0.8	35	+4.8
110–119	138	+1.1	101	+1.4
100–109	127	+1.1	166	+1.7
90–99	116	−0.6	193	−2.2
80–89	75	+0.8	110	−3.3
70–79	41	−0.8	38	−3.5
69 and below	11	+4.0	15	−7.0

* Based on data from Cattell, P. Constant changes in the Stanford-Binet I.Q. *J. educ. Psychol.*, 1931, **22**, 544–550.

time, and mentally deficient children (IQ of 69 or less) changed 7 points—more than average children but considerably less than subjects of superior intelligence (Cattell, 1931).

Long-term Prediction of IQ. We are interested in knowing not only an individual's present intellectual status but also what his future ability will be. What will the IQ of a preschool child be, for example, at the time he enters high school or college? This question of long-term prediction brings us back to the problem of the constancy of the IQ. As we have seen, the IQ may vary considerably, especially if the child is very young at the time of the initial test or if the interval between test and retest is long. Nevertheless, all studies available indicate that certain predictions—much better than chance—may be made concerning future intellectual status. Two excellent longitudinal studies deal with this problem.

The first of these studies involves 40 children who were tested 38 times between the ages of 1 month and 18 years, thus covering the period of men-

tal growth (Bayley, 1949). Individual differences in fluctuation of scores were quite large, especially during the preschool years when the tests available are less reliable. Fluctuations in test scores coincided with shifts in general health, home conditions, and emotional disturbances. For the total group, however, the accuracy of predictability increased as the children grew older. Correlation of IQ's for 18 to 24 months and 42 to 54 months was $+.49$; for 42 to 54 months and 5 to 7 years, $+.82$; for 5 to 7 years and 14 to 16 years, $+.87$; and for 14 to 16 years and 17 to 18 years, $+.96$. Thus the predictive value of the tests depended on the age of the child at the time the test was given. Predictive value is high at any time beyond school age. Correlation for 5 to 7 years and 17 to 18 years was $+.86$, for example, indicating quite a high relationship; if an estimate is made later (for instance, between 14 and 16 years), the correlation coefficient increases to $+.96$.

In the second longitudinal study (Honzik *et al.*, 1948), 252 children were tested at regular intervals from 21 months to 18 years of age. Again, preschool estimates were poor predictors of mature intellectual status. Correlating the scores made at 21 months with those obtained at 18 years produced a correlation coefficient of $+.08$, indicating hardly any relationship at all. Calculations for scores at 3 years and 18 years yielded a higher coefficient, $+.36$, showing somewhat better but still low predictive value. However, if scores at 6 years and 18 years were compared, the correlation coefficient was $+.62$, a fairly substantial relationship. Correlations are frequently not very meaningful, however, so let us examine the extent of changes in the IQ scores between the ages of 6 and 18 years. During this age interval, almost 60 per cent of the group changed 15 or more points, about 30 per cent changed 20 or more points, and about 9 per cent changed 30 points or more. This means that prediction based on tests given at the age of 6 years will err by about 20 IQ points in one direction or the other for roughly a third of the children tested and about 15 points for 60 per cent of the subjects. In view of such large IQ changes, we need to be very cautious in making any kind of prediction concerning mature intellectual status from tests administered during the early years of life.

VARIABLES THAT INFLUENCE INTELLIGENCE-TEST PERFORMANCE

Since the days of the first intelligence tests, it has been demonstrated that a great many factors may influence the level of intellectual functioning. On the one hand, there are cultural factors such as the individual's socioeconomic status, ethnic background, and region of domicile; on the other hand, biochemical factors. Let us look at some of these more carefully.

Biochemical Factors

More and more, recent research indicates that disturbances of the biochemical balance of the body may underlie various disorders of learning capacity and intelligence (see Morgan and Stellar, 1950). For optimum functioning, the nervous system must be constantly supplied with oxygen and the various nutritive elements that provide energy for neural activity. Furthermore, such general conditions as body temperature, pH balance, and hormone secretions can and do influence neural irritability and hence intellectual performance.

Mental Deficiency and Biochemical Factors. Several examples of biochemical influences on intelligence have already been given. In Chapter 2, for instance, it was mentioned that defective genes may lead to defective enzyme functioning, which in turn produces a rare condition known as phenylpyruvic oligophrenia, a type of feeble-mindedness. Less is known about other kinds of mental deficiency, but the little information available suggests that certain types may be due to a failure of the metabolic system during the course of development. Cretinism, caused by underactivity of the thyroid gland in childhood, furnishes a good illustration of such early metabolic impairment. Another type of feeble-mindedness believed to reflect disturbed metabolic function is *mongolian idiocy*. Little is known about this condition apart from the fact that it is more prevalent in infants born when their mothers were advanced in years. Research indicates that the cretin, mongolian idiot, and phenylpyruvic oligophrenic have one thing in common—defective cerebral metabolism. Himwich and Fazekas (1940), for example, demonstrated that the brains of individuals suffering from these conditions lack the ability to use normal amounts of oxygen and carbohydrates.

Anoxia. Because of the importance of oxygen to nerve function, considerable research has been done on the effects of oxygen deprivation (*anoxia*) on learning and intelligence. In general, the conclusions have been that slight oxygen reduction has no marked effect but that severe deprivation impairs judgment, perception, and psychomotor performance as well as intelligence-test scores (see Shock, 1939).

Oxygen deprivation at the time of birth may have serious effects on later behavior. Schreiber (1939), who studied 250 mentally deficient children, found that approximately 70 per cent had suffered severe asphyxiation at birth as opposed to 5 per cent of normal children. This finding is supported by Windle and Becker (1943), who induced anoxia experimentally in newborn rats. When learning ability was tested several months later, it was found that these rats compared unfavorably with normal animals.

Nutritional Factors. Several studies demonstrate the effect of nutrition on intellectual performance. In one investigation, a group of children who were malnourished according to physicians' diagnosis were matched with a control group. The nutrition level of the experimental group was improved for a period of 1½ to 2 years. This treatment raised the IQ level of experimental subjects about 10 IQ points, while the control group remained constant. The rise in IQ was most marked when improved nutrition was introduced during the first 4 years of life; little effect was seen on older children (Poull, 1938).

Role of Thiamin. Of the various nutritional components, thiamin, one of the B-complex vitamins, has been studied most extensively. It is believed that this vitamin is important to intellectual functioning because of its intimate relationship to optimum functioning of the nervous system (co-enzyme in metabolism). One investigator divided 110 orphanage children into an experimental and a control group, matched for length of residence, education, IQ, sex, and other factors. Diets of experimental subjects were supplemented with thiamin for a period of a year; control subjects received placebos. When tested at the end of the year, experimental children showed a significant improvement in various intellectual tasks (Harrell, 1947).

Other studies have failed to provide clear-cut evidence on the beneficial influence of thiamin. Among these studies, perhaps the best evidence comes from Bernhardt *et al.* (1948), who studied 36 pairs of identical twins, giving one twin thiamin and his co-twin placebos for a period of 18 weeks. Although some gains on some mental tests were observed in experimental twins, the differences were not statistically significant. Essentially similar results were obtained in an earlier study (Balken and Maurer, 1934).

This lack of agreement on the effects of thiamin is undoubtedly due to several variables such as the length of the treatment period and the nutritional status of the subjects involved. Another possible variable is the age at which the vitamin supplement was administered. Animal studies have established that if thiamin is given or withdrawn during infancy, improvement or deterioration may be observed on later maze learning; however, if thiamin is given or withdrawn later, no effect on learning is noted (see review of this topic in Morgan and Stellar, 1950). Unfortunately, this age variable has not been considered in human studies.

Role of Glutamic Acid. It has been suggested that glutamic acid, an amino acid which reactivates one of the enzymes involved in neural transmission, may accelerate mental growth. Zimmerman *et al.* (1947) reported some astounding IQ increases on administering glutamic acid to eight children of subnormal intelligence. This study has been severely criticized, however, on the grounds of the small sample and of inadequate controls, and hence these findings can be regarded only as suggestive.

In summary, it may be said that improvements in IQ may occur following administration of vitamin supplements or other dietary elements. Why these improvements appear in some studies and not in others remains to be discovered.

Endocrine Factors. As noted earlier, mental deficiency may result from endocrine malfunction. In cretinism resulting from hypothyroidism, for instance, mental functioning may be improved by the administration of thyroid hormone at an early age.

Apart from the evidence already discussed, there are no studies on human beings. In the animal field, Scow (1946) found that removal of a part of the thyroid glands of rats at birth impaired later learning. Riess (1947), who tried administering adrenal-cortical hormones to rats, found some improvement in maze performance—the experimental animals required as much time as controls but made fewer errors. He believed that the reduction of errors was due to steroid-hormone facilitation of carbohydrate metabolism, crucial to neural functioning. In general, however, attempts to influence learning ability by hormone injection or by extirpation of glands have produced negative results.

Improving Intelligence in Old Age. Chapter 9 mentioned the work of Caldwell and Watson (1952), who gave hormone treatments to 30 senescent females whose mean age was 75 years. Half of these subjects were given estrogen and progesterone injections sufficient to induce cyclic menstrual bleeding, while the other half were given only neutral oil. Although hormone injections over a 6-month period appeared to improve such mental functions as memory, no significant differences appeared on comparing initial and retest scores of the Wechsler-Bellevue test. The investigators conclude that "intellectual functioning, although not uniformly at a higher level, does show some improvement in so far as ability to think and willingness to expend intellectual energy are concerned." Moreover, "over the six months period, the experimental group made distinct gains in ability to learn new material." This study is still in progress, and it is possible that later reports after $1\frac{1}{2}$ years of treatment will bring out more clear-cut results.

Cultural Factors

All intelligence tests have a cultural reference, that is, they reflect cultural experiences and indicate how well an individual deals with cultural artifacts. Since this is so, we might anticipate that an individual's IQ will be influenced by a variety of cultural factors.

Parents' Occupation. Extensive investigations with the Stanford-Binet tests have revealed pronounced differences in the IQ's of children whose parents belong to different occupational groups. Figure 82 shows the results of one such study (McNemar, 1942). According to these data, chil-

dren of professional parents have a mean IQ of about 115, and children of day laborers, a mean IQ of 94. The IQ's of intermediate occupational groups consistently fall between these two extremes. While this evidence is supported by numerous other studies, interpretation of the findings is more difficult. The most frequent explanation is that only persons of higher intellectual ability may be expected to reach the higher occupational groups and that their superior ability is presumably passed on to their offspring. A factor often overlooked is that parents in the higher occupational groups are able to provide a better environment for their children through such things as more and better books, better schools, and
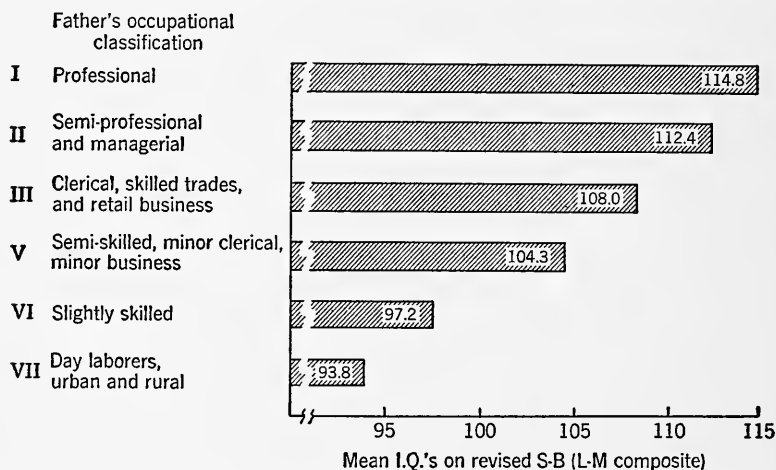
FIG. 82. The relationship between parents' occupation and intelligence level of children, according to Stanford-Binet tests. (*Based on data of McNemar, 1942. From Thompson, G. G. Child psychology. Boston: Houghton Mifflin, 1952. P. 413. By permission of the publishers.*)

even better playthings. Hence both heredity and environment may effect occupational differences.

Socioeconomic Status. Socioeconomic status is a more comprehensive grouping than occupation, since it usually includes such other factors as education, source and level of income, ethnic origin, and residential area. Because of the complexity of the classification itself, it is difficult to interpret findings in this area, for few investigators include the same variables or weightings in assessing the socioeconomic status of their subjects. However, we must of necessity group all such studies in this section.

Bayley and Jones (1937) found that the correlation of socioeconomic status and IQ increased from age 3 to 6, the period studied. Prior to the age of 3, the relationship was slight; by school age, it was marked. Of the various factors included in the socioeconomic index, parents' education yielded the highest correlation with children's IQ, while social rating and

income level showed the smallest relationship. These findings have been corroborated by numerous other investigations on children ranging from nursery school through college. Goodenough (1946) cogently sums up as follows:

. . . That performance on intelligence tests varies according to the social class from which the subjects are drawn has been recognized since the days of Binet. That the relationship is not one of simple cause and effect is demonstrated by the fact that every level of intelligence can be found within each social level, though not in equal proportion. A greater percentage of the bright children come from families of superior socio-economic status, whereas the frequency of backward children is proportionately greater among the lower social classes. The relationship is sufficiently marked to bring about a difference of 20 to 30 IQ points in the mean test standing of children of college professors and those of day laborers [p. 470].

Socioeconomic differences in IQ have been attributed to the same factors which account for occupational differences. In a fluid society, the more intelligent tend to rise in the socioeconomic scale and to remain there, while the less intelligent gravitate downward and remain in the lower strata. Once again, the upper strata are able to provide a more stimulating environment for their children, whose potentialities for mental growth are better realized in consequence. Some investigators suggest another cause of the IQ differential; they believe that present-day intelligence tests are so constructed as to favor the children in the upper socioeconomic brackets by virtue of the items used in these tests (*e.g.*, Neff, 1938). This, they say, is particularly true of the Binet type of test, with its high linguistic component. Havighurst (1949), for example, believes that current intelligence tests favor not only certain socioeconomic strata but also professional groups such as the one to which psychologists belong. Although the nature of the tests used may play a role, it is likely that much of the differential relates to the first two factors mentioned.

Regional Influences. There is fairly clear evidence that regional location is correlated with performance on intelligence tests. This is especially noticeable when rural children are compared with urban children. McNemar (1942), for instance, observed that the mean IQ of urban children was 108; of suburban children, 107; and of rural children, 96. Several factors contribute to these differences. First is selective migration. During the past decades, the more progressive families have tended to move toward the superior economic and cultural opportunities of the city, while the less ambitious remained in rural areas. Secondly, the city offers better schools and better educational facilities, attracts better teachers, affords a wider variety of extracurricular and recreational activities, and thus presents a greater challenge to the growing child. Thirdly, present-day

intelligence tests have been standardized primarily on city children. Probably all these and other factors contribute to the IQ differences.

Broader regional differences have also been reported. These may parallel the educational opportunities available in different states; for example, in the United States, Negro children in the Northern states score higher than Negroes in the Southern states.

Effect of Impoverished Environment on IQ. In the above discussion it was suggested that differential IQ's may depend to some extent, at least, on the kind of environment in which children are reared. The role of environmental influence on intellectual performance becomes clearer when we study children who have grown up in isolated rural communities where the opportunities for maximal development of intellectual potentialities are limited. Educational facilities in such places are poor; outside contacts are rare. Several studies which have been carried out in such areas indicate that the youngest children have IQ's near the normal but that, as they grow older, their IQ's decrease progressively. Let us look at some of these investigations.

Mountain Children. Asher (1935) found that the IQ's of 7-year-old Kentucky mountain children averaged 83; by the age of 15, IQ's of the same children had dropped to 61. Wheeler (1932, 1942), who made an extensive survey of over 3,000 children attending various mountain schools in east Tennessee, noted a similar decline in intelligence throughout the school years. The IQ's of 9-year-olds averaged 95 (well within the normal range); at 15 years, the mean was 73. Wheeler's interpretation is interesting; he believed that "the mountain children were not as far below the normal as the tests seem to indicate," but that they were "victims of a starved environment which had an increasing effect on their intellectual performance as they grew older." About 10 years later, when Wheeler returned to the same communities and retested essentially the same families, he observed that while there was a similar decline in IQ with increasing age, the decrease was relatively small. The over-all improvement was attributed to an advance in socioeconomic and educational facilities during the intervening years.

Canal-boat Children. A similar situation exists in countries other than the United States, as demonstrated by a well-known survey carried out in England. Subjects were canal-boat children who came from poor home environments where parents were illiterate and who rarely, if ever, attended school. The IQ's of most of the youngest children ranged from 90 to 100; by late childhood, however, they were considerably below normal (cited by Neff, 1938). Evidently impoverished environments, poor educational facilities, and a lack of opportunity for intellectual stimulation become increasingly important as age increases. In discussing this problem, Boring *et al.* (1948) state: "The intellectual requirements of a

three-year-old can be satisfied about as adequately on a canal boat or in an isolated mountain community as in a prosperous urban home. The older child, however, with his broadening intellectual needs, will be seriously affected by these environmental limitations."

Animal Support. Some recent animal work gives further support to the thesis that an impoverished environment in early life may influence later intellectual performance. In an experiment carried out at McGill University, a group of puppies were taken away from their mothers at the time of weaning and were placed in cages—two to a cage—where they were reared in isolation. During this period of confinement they never saw the external environment outside the cage nor were they handled by the caretaker. Their litter mates were reared under the usual laboratory conditions. After several months of solitude, all were tested on a maze very like the Porteous maze used to appraise intelligence of human beings. It consisted of a large enclosure in which movable barriers were shifted from day to day so that the animals had to learn to find food by a different route each day. The "restricted" animals proved to be considerably inferior to their litter mates in maze learning. When retested several years later, they were still significantly inferior to the controls, even though some had spent the intervening time with the control animals and others had been given away as pets. The inferiority of the restricted animals was evident in almost any problem-solving situation (*e.g.,* delayed reaction, detour problems) (Clarke *et al.,* 1951; Thompson and Heron, 1954). Thus it seems that depriving animals of environmental stimulation during infancy produces long-lasting impairment of problem-solving ability.

Effect of Enriched Environment on IQ. We have just seen that if a child is reared in a meager, unstimulating environment, his intellectual performance suffers as a consequence. Now one might well ask what the effect would be of transferring a child from such an impoverished environment to a better one. Fortunately, there are several studies dealing with this question.

In one of these investigations, children living in an impoverished orphanage were transferred to a well-equipped and well-staffed nursery school for a period of $\frac{1}{2}$ to $2\frac{1}{2}$ years. At the end of this period, their IQ's were compared with those of a control group which had remained at the orphanage. The IQ's of the controls declined during the course of the study; IQ's of the experimental group improved. The amount of improvement depended on the duration of their residence at the nursery school— the longer the time, the greater the increase (Skeels *et al.,* 1938).

In a second study, children of different ages were transferred from a poor home environment to a highly stimulating model child city (Mooseheart), where they remained for 5 years. IQ's were determined at the time of entrance, after 1 year, and at the end of the 5 years. The results are

recorded in Table 19. The enriched environment evidently had little or no effect on the intelligence of the children over the age of 7 years. There was some improvement in younger subjects, most of it occurring during the first year of residence. Seemingly, if a superior environment is to have any beneficial effect, it must be provided very early in life.

TABLE 19. EFFECT ON IQ OF CHILDREN ENTERING A HIGHLY STIMULATING ENVIRONMENT*

Age at entrance	N	IQ at entrance	IQ 1 year later	IQ 5 years later
6 years and under.......	30	97	102	103
7, 8, 9, years............	40	96	97	97
10 to 14 years...........	30	92	92	92

* Based on data of Reymert, M., and Hinton, R. T. The effect of a change to a relatively superior environment upon the IQ's of one hundred children. In 39th Yearb. Nat. Soc. Stud. Educ., Part II, 1940. P. 261.

Animal Support. The beneficial effect of an enriched environment in early childhood receives some support from further animal work carried out at McGill University. One investigator took home a group of rats and reared them as pets from infancy on, permitting them to run around the house at will most of the time. Controls were reared in the ordinary cages found in all laboratories. When the rats reached adulthood, both groups were tested on a maze similar to that used in the dog experiment described above. Comparison of test scores revealed that the pet, or "free-environment," rats performed at a level far superior to that of cage-reared animals. Moreover, later tests indicated that the free-environment rats continued to be superior to the restricted rats. The experimenter concluded that "the richer experience of the pet group during development made them better able to profit by new experiences at maturity . . . one of the characteristics of the 'intelligent' human being" (Hebb, 1949).

These findings have been corroborated by more recent work in which the original conditions were repeated except for the locale of the free environment. Instead of being allowed to run around the house, rats were placed in a complex environment constructed within a large cage—ladders, swings, tunnels, etc., constituting the complex element. Again animals reared in such surroundings were superior to control animals in maze performance. The enriched environment had to be provided in early infancy in order to be effective, however (Hymovitch, 1952; Forgays and Forgays, 1952; and personal communication). These animal studies are in line with data on human beings and indicate that enriched experience in early life can influence later intellectual performance.

INTELLECTUAL DEVELOPMENT AND DECLINE

So far, we have been concerned with general factors relating to intelligence. Now we are ready to examine the nature of intellectual functioning from infancy to old age. First we shall discuss the growth and decline of intelligence as evidenced by total scores on such individual tests as the Wechsler-Bellevue and such group tests as the Army Alpha or the Otis; next we shall look at the age changes in the various components that contribute to this "general" ability.

Growth and Decline of "General" Intellectual Ability

Age of Cessation of Mental Growth. As children grow, they exhibit progressively greater intelligence both on formal intelligence tests and in everyday behavior. Mental growth is rapid in the early years of childhood but begins to slow down around the age of 12 or 13, with yearly increments subsequently becoming smaller until growth ceases. The growth curve is therefore represented as a fairly regular line which begins to taper off around puberty.

Investigators disagree concerning the precise age at which intellectual growth ceases. According to Terman and Merrill (1937), performance on the Stanford-Binet tests reaches a maximum around the age of 16 years. Others place peak performance in the late teens or early 20's (*e.g.*, Freeman and Flory, 1937). The disagreement may be due to several variables such as the nature of the test used or the individual's ability level. For example, individuals of superior ability continue to improve on Stanford-Binet performance until the age of 18, and those of normal intelligence until the age of 15 or 16, while subjects of low intelligence reach a peak at 14 years or even earlier.

Changes in Intelligence throughout the Life Span. Figure 83 illustrates intellectual development and decline as appraised by three separate studies employing three different intelligence tests. Each curve is based on data on a large number of subjects thought to be fairly representative of the general population. Jones and Conrad (1933) used a group test, the Army Alpha; Miles (1932) also used a group test, the Otis; and Wechsler (1944) worked with an individual test, the Wechsler-Bellevue. In all three studies, intellectual performance increases during childhood and adolescence to reach a maximum around the age of 20, after which it begins to decline fairly rapidly. The rate of decline differs on the three tests, however; the Otis scores drop most rapidly and the Army Alpha most slowly. This differential rate of decline is undoubtedly related to differences in nature of subtests included in the two batteries (the Otis is entirely verbal; the Army Alpha has, in addition, some nonverbal items).

Amount of Decline as Function of Initial IQ Level. The preceding section concerns development and decline in intelligence of the over-all population. Next the "average" curves seen in Fig. 83 will be broken down into a series of curves representing different IQ levels. Figure 84 illustrates such a breakdown for the Otis test mentioned in the previous section (Miles and Miles, 1949). In this diagram the six curves represent IQ's ranging from 130 down to 80. All of them increase to reach a maximal level in the late teens; all remain stationary for several years and then decline.

The important point, however, is that although the six curves all decline they do not reach the same ultimate level. At the age of 80, the indi-
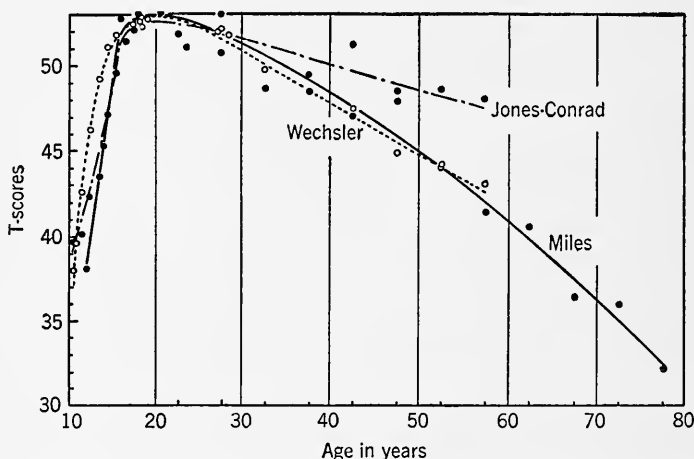
FIG. 83. Changes in intelligence with age as shown by three studies. (*Based on data of Miles and Miles, 1932; Jones and Conrad, 1933; and Wechsler, 1944. From L. A. Pennington and I. A. Berg (Eds.), An introduction to clinical psychology. New York: Ronald, 1948. P. 226. By permission of the publishers.*)

vidual whose IQ was 130 in early adulthood still has an IQ of 115 or more —about the level of the average university student; the person whose IQ was a normal 100 in earlier years has dropped to 85—a low normal; the one who was low normal in early adulthood has dropped to a subnormal level by the age of 80 years. This means that many old people continue to be alert in old age, even though many have deteriorated below the normal young-adult level. The young "average" college student with an IQ of 115 can expect to remain well within the normal intelligence range when he is an octogenarian; a few may even remain in the very superior, or genius, category.

Although it has been known for many years that "intelligence declines in old age," this decline has not always been considered from the viewpoint of differential decrements. Certainly these facts should prompt us to think more seriously about such socioeconomic problems as universal re-

tirement at a fixed age. Some individuals are undoubtedly incapable of working; others may continue to be more capable than the average (if not the majority) of their younger colleagues, and, as we shall see later, they prefer work to retirement on pension.

Influence of Environment in Later Life. There is little evidence on the influence of environment on IQ in later life. Fox (1950) compared the Wechsler scores of two groups of elderly subjects, matched for age, educa-
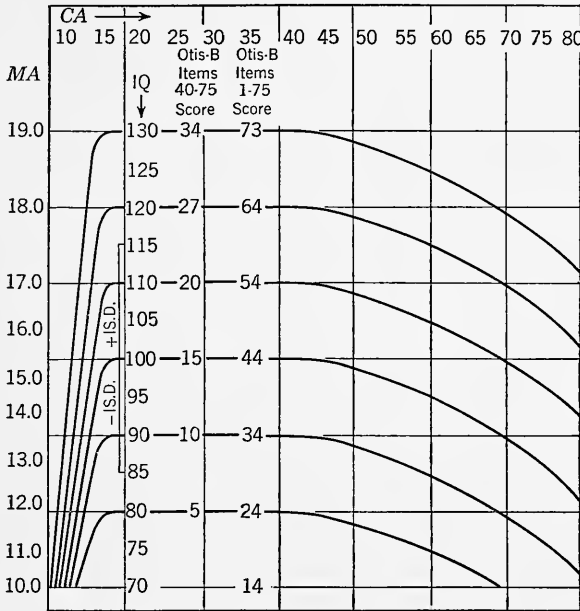
FIG. 84. Smoothed curves indicating the influence of age on intelligence-test scores of adults of different ability levels. (*From Miles, W. R., and Miles, C. C. Mental changes with normal aging. In E. J. Stieglitz (Ed.), Geriatric medicine. Philadelphia: Saunders, 1949. P. 97. By permission of the publishers.*)

tion, and occupational background. The experimental group consisted of 25 subjects with a mean age of 71.7 who had been admitted to a public home because they could no longer maintain themselves independently. They were tested within 10 days of admission. The control group was comprised of 25 subjects whose mean age was 71.8 and who continued to live in the community with the aid of pensions. The IQ's of all subjects were calculated for the total Wechsler battery as well as separately for verbal and performance scales. Fox found no significant differences between the two groups on any measure. On the full scale, experimental subjects had an average IQ of 94.0 as compared with 95.2 for the controls. Differences in IQ were evidently not responsible for the failure of the experimental subjects to maintain themselves in later life. Although the

groups were well matched on some essential factors, the numbers involved were too small for any conclusion to be drawn. Further study is needed— perhaps a comparison of institutionalized old people with others who are able to maintain themselves in the community without any financial assistance. A longitudinal study continued from the time of admission for several years would also be interesting, since it might throw some light on the effects of restricted environment in old age. We shall not minimize the difficulties involved in controlling variables in such a study, however.

Influence of Heredity in Later Life. Kallmann and Sander (1949) have provided some excellent data on twins in later life. They studied 1,602 twin cases over the age of 60. Of these, 697 were males and 905 females; 237 were monozygotic, or identical, twins and 548 definitely dizygotic. Life histories were available for all cases. While much of the study concerned persistent physical similarities, mental abilities were also compared.

To appraise intellectual performance, 77 pairs of females ranging in age from 60 to 87 were selected. Their educational backgrounds varied from elementary school in rural areas to highly specialized professional training. Various measures, including Wechsler and Binet subtests, were used. On all tests, the average scores for identical and for fraternal twin pairs were fairly similar. When subtests were compared separately, it was found that in four out of six subtests (vocabulary, Koh's blocks, digit span, and digit-symbol substitution), the mean differences between identical twins were smaller than the mean differences between fraternal twins (results significant at a 0.01 level of confidence). Kallmann and Sander conclude that "all the available data serve to show . . . that the genetically determined likenesses of monozygotic twin partners have a tendency to persist throughout life."

Growth and Decline of Various Subabilities of Intelligence

The preceding section pointed out that intelligence as measured by both individual and group tests begins to decline fairly rapidly soon after the age of 20 years. The picture becomes less gloomy when the age changes in various components, or subabilities, of intelligence are examined. Certain abilities show no age decrement; some do not decline until a relatively late age; while others begin to fall off rapidly after attaining their peak. Let us examine some relevant studies.

Differential Decline of Subabilities of the Army Alpha Test. In Fig. 85 we see the Army Alpha broken down according to its eight subtests: oral direction, dissected sentences, arithmetic problems, numerical completions, common sense, analogies, vocabulary, and general information. The eight curves represent age changes from 10 to 60 years. All subtests are characterized by uniform and rapid improvement throughout childhood
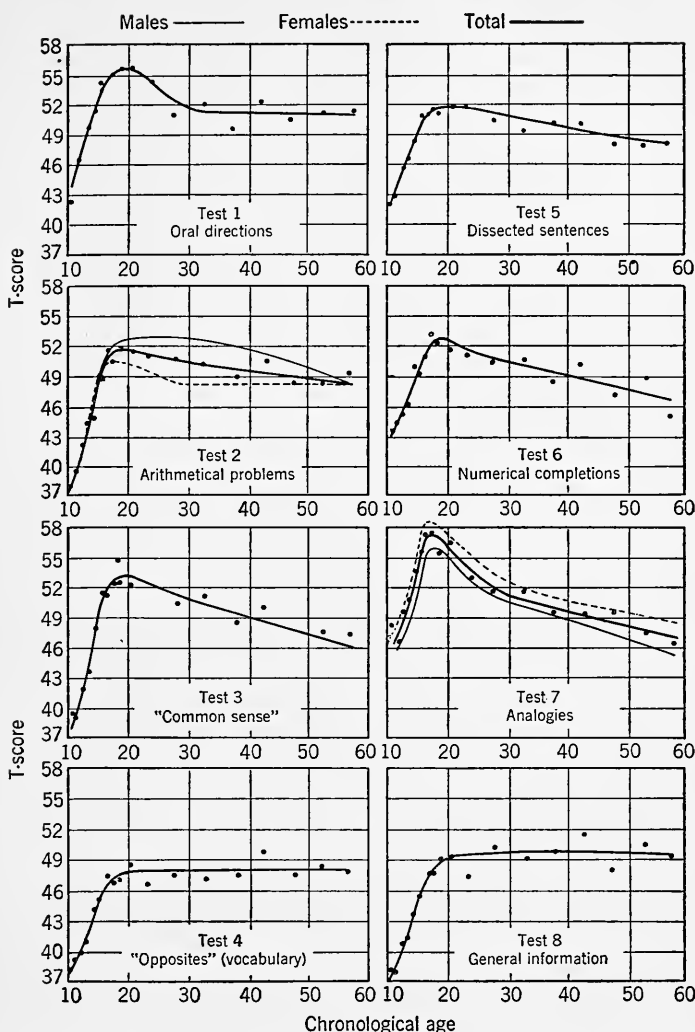
FIG. 85. Growth and decline of ability in the individual subtests of the Army Alpha. (*From Jones, H. E., and Conrad, H. S.   The growth and decline of intelligence: a study of a homogeneous group between the ages of ten and sixty. Genet. Psychol. Monogr., 1933,* **13**, *250. By permission of the Journal Press.*)

and the teens, reaching peak performance around the age of 20; from this point on, they differ. Vocabulary and general information show no age decrement; performance at 60 is on a par with that at 20 years. Five of the subtests—dissected sentences, arithmetic problems, numerical completions, common sense, and analogies—evidence progressive decline from age 20 on, but their rates of decline vary. Decrements are most pronounced for analogies and only slight for arithmetic problems, for ex-

ample. The curve representing oral directions is most unusual, since it shows rapid decline during the third decade and then levels off with no further drop.

"Hold" and "Don't Hold" Wechsler Subtests. Wechsler (1944) recognized differential rates of decline of the various mental abilities, and in his manual of directions for the Wechsler-Bellevue Scale he divided the subtests into two groups which he called the "hold" and "don't hold" subtests. According to this source, subtests which hold up with age include information, comprehension, object assembly, picture completion, and vocabulary. On the other hand, arithmetic, digit symbol, block design, similarities, and picture arrangement fail to hold up as age advances.

When these subtests are compared with the Army Alpha, it will be noted that some items present in one battery are absent in the other but that some—*e.g.*, comprehension—"hold" according to Wechsler and decline according to Jones and Conrad (see Fig. 85). Such discrepancies caused Hunt (1949) to reanalyze the Wechsler data, testing all apparent differences by rigid statistical formulas for each age level. He concludes that Wechsler's calculations erred and that

. . . only information and comprehension can be said to hold up with age. In the case of the other six tests, the differences are statistically significant and they apparently do not hold up with age. The "Hold" tests, Object Assembly and Picture Completion, for example, apparently do not hold up as well as Arithmetic, one of the "Don't Hold" tests. Picture Completion does not hold up as well as Digit Span, another reversal of what might be expected according to Wechsler's hypothesis [p. 443].

Recent Evidence of Differential Decline of Wechsler Subtests. Recently Berkowitz (1953) has supplied some information about the nature of age changes on the various subtests of the Wechsler battery. His sample consisted of over 1,200 males, aged 20 to 84, 1,000 of whom were over the age of 50. These subjects, all from New York State, represented various social backgrounds and occupations. The scores obtained by the various age groups are recorded in Table 20. In line with earlier findings, vocabulary and general information show no age decrements. Such subtests as digit symbols, block design, and picture arrangement, however, exhibit progressive decline from the early 20's onward. The remaining subtests—object assembly, comprehension, digit span, and similarities—show progressive decline from the 20's into the late 50's and then level off with no further decrement throughout the later years.

Nature of Intellectual Changes as Shown by Factor Analysis. A different approach to the study of age changes in intellectual capacities is offered by the factor-analysis technique. One study of this kind is reported

by Balinsky (1941), who analyzed the performance of subjects aged 9 to 60 years. His 563 subjects were divided into six age groups: 9, 12, 15, 25 to 29, 35 to 44, and 50 to 59 years. All subjects were given the complete Wechsler-Bellevue test, and the results were broken down by factor analysis.

Balinsky reported some extremely interesting findings, which are summed up in Table 21 to clarify age differences. Eight factors contributed to the test results, but, interestingly, none of these carried through all age levels. The verbal factor was readily isolated in results of the first

TABLE 20. AGE CHANGES IN MEAN RAW SCORES ON VARIOUS SUBTESTS OF THE WECHSLER-BELLEVUE TEST OF INTELLIGENCE[*]

Age	N	Verbal subtests						Performance subtests				
		Information	Comprehension	Digit span	Arithmetic	Similarities	Vocabulary	Picture arrangement	Picture completion	Object assembly	Block design	Digit symbol
20–24	24	13.75	12.04	11.04	6.58	11.67	22.66	12.17	10.74	18.74	21.18	37.00
25–29	52	13.40	11.90	10.23	6.88	10.73	21.94	9.90	10.39	18.65	20.82	36.90
30–34	33	14.88	12.03	9.97	7.09	12.42	24.89	9.97	10.88	19.00	21.38	35.91
35–39	41	13.22	11.12	10.80	6.85	9.93	22.42	9.70	10.08	17.80	17.18	34.50
40–44	25	12.64	10.04	10.24	6.67	9.08	21.88	8.00	10.04	16.75	15.40	28.20
45–49	32	14.00	10.81	9.56	6.55	9.69	22.11	7.76	10.14	16.52	14.50	26.11
50–54	216	14.66	10.81	9.58	6.51	9.61	22.74	6.48	9.62	16.14	14.35	24.63
55–59	404	13.02	9.47	9.60	5.78	7.94	21.67	5.74	8.83	15.10	12.82	20.71
60–64	278	12.70	8.59	9.20	6.78	6.78	20.17	5.38	8.36	14.36	11.59	19.54
65–69	64	13.14	9.52	8.87	5.32	7.57	21.90	4.76	8.31	14.13	10.43	17.58
70–74	33	13.61	9.79	9.24	5.30	7.73	22.87	4.13	8.26	14.48	9.83	18.00
75–79	24	14.14	9.24	9.35	6.33	8.81	22.24	5.29	7.88	15.35	8.82	15.65
80–84	7	10.14	7.57	9.14	5.00	6.14	19.64	2.57	7.29	9.00	6.14	6.71

* From Berkowitz, B. The Wechsler-Bellevue performance of white males past age 50. *J. Geront.*, 1953, **8**, 77, 78. Used by permission.

five age groups (9 to 44) but was absent or unidentified in the oldest subjects (50 to 59). The performance factor emerged in all but the youngest group. These two factors appeared most consistently. A general, or "G," factor was found in the oldest and the youngest groups but not at other ages. A factor which Balinsky called "seeing relationships in social situations" appeared only in the test results of the 12-year-olds—interestingly, at an age when great emphasis is placed on social *savoir-faire* and training and when the preadolescent resents social pressures more than at any other age. Another factor called "restriction in solution" emerged in young adolescents but was absent in both earlier and later years. A "factor involving some sort of reasoning" was peculiar to the oldest subjects of this sample.

It would be premature to accept these factors as well established for the various age levels. However, the study is important because it suggests that not only does intelligence change with age but the contributing factors may also change. Balinsky himself believes "that the mental traits change and undergo reorganization over a span of years." On calculating intercorrelations for various subtests, he found that they were relatively high at 9 years ($r = +.43$), gradually decreasing to the years 25 to 29 ($r = +.18$), and then increasing again to the last group (50 to 59) ($r = +.43$). He interprets these changes as a gradual differentiation of abilities followed by reorganization and restriction.

TABLE 21. FACTORS IN WECHSLER-BELLEVUE TEST RESULTS FOR AGES 9 TO 60*

Factor	9	12	15	25–29	35–44	50–59
General...........................	1	—	—	—	—	1
Verbal............................	1	1	1	1	1	
Performance.......................	—	1	1	1	1	1
Seeing social relationships...........	—	1				
Memory...........................	—	—	—	1	1	
Restriction in solution...............	—	—	—	1		
Kind of reasoning...................	—	—	—	—	—	1
Unidentified.......................	—	—	1			

* Based on data from Balinsky, B. An analysis of mental factors of various age groups from nine to sixty. *Genet. Psychol. Monogr.*, 1941, **23**, 191–234.

Aging in the Mentally Deficient. We have been concerned so far with age changes in the normal population. Although this text is primarily interested in the normal, two studies on deviates—first the mentally deficient and then the mentally superior—will be presented.

Thompson (1951) investigated the aging process in 137 mentally defective subjects with IQ's of 50 to 70, ranging in age from 16 to 69 years. Ten performance tests were used, including three subtests from the Wechsler-Bellevue battery (picture arrangement, digit-symbol substitution, and block design), three from the Stanford Later Maturity Scale (measures of symbolic processes such as series completion, picture completion, and color tests), and four others of similar caliber. Thompson reports a significant age decrement on all 10 subtests. Most interesting, however, was the finding that the nature of decline differed from that of the normal population. No decrease on any test appeared before the age of 30, when an abrupt decline set in. Following this no further decrements appeared throughout the age range studied. In the case of two verbal tests, digit span and the vocabulary test of the Wechsler, no decrement whatever occurred between the ages of 16 and 69 years. We may thus conclude that

persons in the lower IQ ranges differ from normal subjects with respect to onset of mental deterioration and pattern of decline.

Aging in the Mentally Superior. At the upper extreme of the normal-probability curve are the mentally superior. Sward (1945) made a study of aging in such a group. He selected 45 university professors, aged 60 to 80, who were all sufficiently eminent to be listed in *American Men of Science*. This experimental group was compared with a similar control, consisting of 45 younger academic men, aged 25 to 35, matched for field of specialization. Eight tests were given: (1) ingenuity problems, (2) learning an artificial language such as pig Latin, (3) synonyms and antonyms, (4) symbol-digit substitution, (5) number series completion, (6) word meanings, (7) analogies, and (8) arithmetic problems.

The younger men surpassed their seniors on all tests except word meaning, in which they equaled the older men, and on synonyms and antonyms, in which the older men were superior. The over-all picture, however, shows a great deal of overlap on all tests, some older men surpassing some younger subjects. On the total battery, 96 per cent of the younger men exceeded the median scores of the older group, while 80 per cent of the scores of the older subjects fell within the lowest quartile of the control distribution. On the synonym-antonym subtest, 80 per cent of the older men surpassed the median for the younger controls. These findings are entirely in line with other studies. Thus, even within the higher IQ range, a certain amount of decline occurs in most of the mental abilities and on the over-all IQ.

Vocabulary Tests. Quite a number of investigators have studied age changes in vocabulary. Since early-age changes have already been discussed (Chapter 9), this section will be limited to later-age changes as appraised by subtests of the Wechsler-Bellevue, Stanford-Binet, and other intelligence tests. It was mentioned earlier that Jones and Conrad (1933, see Fig. 85) reported a decline in such language functions as analogies and dissected sentences but a constant level for vocabulary—at least until the age of 60. Berkowitz (1953), too, found that vocabulary remained constant into the late 70's, while Wechsler (1944) included vocabulary among the "hold" subtests.

The constancy of adult vocabulary level is supported by Thorndike and Gallup (1944), who tested 2,974 subjects aged 21 to 60, following the sampling technique of the American Institute of Public Opinion. Shakow and Goldman (1938), using the Binet vocabulary list for 203 subjects aged 18 to 90 years, found no age differences. Others agree with this finding (*e.g.*, Fox, 1947; Eysenck, 1945; Halstead, 1943; and others). Not all of these samples included extremely old subjects, however. Several investigators who have tested large samples over the age of 60 report that vocabulary level remains constant until the age of 70 but shows some slight

decline thereafter (*e.g.*, Shakow *et al.*, 1938, 1941; Foulds and Raven, 1948). Brown (1948), who compared the vocabulary of 26 college students with that of 22 residents in a home for the aged, found the quality of vocabulary poorer among the older subjects. Feifel (1949) reports similar findings, while others fail to corroborate such a qualitative difference. It is likely that education level and socioeconomic status played a more important role than age in determining the vocabulary quality.

Studies Indicating Increased Vocabulary in Old Age. Although a few investigators have reported decline in vocabulary in old age, others report increases in later years. Sorenson (1933), for example, studied 641 subjects selected randomly from among 6,000 extension students at the University of Minnesota, whose ages scattered from 15 to 70 years. He found a gradual increase in vocabulary rating covering this age range and still increasing in the 60-to-70-year group. Christian and Paterson (1936) reported a similar increase to the age of 60 and a slight increase beyond this to age 70 in superior subjects. Rabin (1947) found that vocabulary scores increased gradually but progressively as age advanced. According to his data, the score for age 20 and under was 49.3; for ages 40 to 49, 54.6; and for an older group with a mean age of 65 years, 57.5. Rabin's findings are especially interesting because of the differential education level of the three groups: the younger group had the highest education level and the lowest vocabulary scores; the oldest group, the lowest education level but the highest vocabulary scores. This suggests that vocabulary scores are independent of general educational achievement.

Age Changes in Vocabulary in Relation to IQ Level. These and other studies have been widely reviewed by writers who criticize sampling especially. Perhaps some new light may be thrown on both results and criticisms if the problem is looked at from the viewpoint of a British investigator, Raven (1948), who analyzed age changes in vocabulary as a function of intellectual ability.

Raven's studies involved approximately 8,000 subjects, ranging in age from 6 to 60 years and varying in IQ level. The results of his vocabulary appraisal are illustrated in Fig. 86. An examination of this graph reveals that subjects of superior ability (top 5 per cent of the population) continue at a constant level throughout the age range measured; persons of average ability reach "vocabulary maturity" later, are consistently inferior to the top group at all age levels, and decline slightly toward the age of 60 (and presumably beyond this age), as far as vocabulary scores are concerned; persons of inferior ability are the slowest in reaching maturity, they are consistently poor at all age levels, and ability declines earlier and more markedly than in any other group.

Any marked decline in vocabulary ability thus applies to only the lowest 25 per cent of the population. The picture might change again if we

were to study the lowest 5 per cent, for instance. Unfortunately, Raven tested such a group only up to age 25. However, his data may be supplemented by Thompson's (1951) investigation, which was mentioned earlier. It will be recalled that his subjects, aged 16 to 69 years, were mentally inferior, with IQ's below 70. Thompson found no vocabulary decrements throughout the age range studied. If his observations are coupled with Raven's work, it can be seen that neither the top nor the bottom extreme of the intelligence range shows any decrease in vocabulary in old
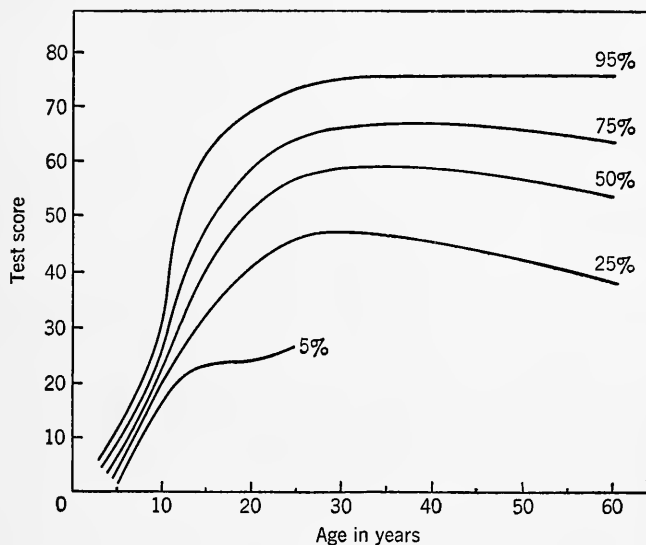
FIG. 86. Age changes in vocabulary-test scores in subjects of below-normal, normal, and above-normal intellectual ability. (*From Raven, J. C. The comparative assessment of intellectual ability. Brit. J. Psychol.*, 1948, **39**, 16.)

age. Between these extremes there is a varying amount of decline. These findings indicate that much of the controversy regarding constancy, increase, or decrease in vocabulary with age may be resolved on a basis of sampling, for different investigators may have studied subjects of different intellectual levels.

Speed, Power, and Breadth Tests. It was observed earlier in this chapter that most intelligence tests are constructed to tap speed, power, or breadth. The differential decline on tests involving speed has already been discussed (see Chapter 9) and will be mentioned only briefly here. Sward (1945), who studied mentally superior individuals, found that speed-test scores deteriorated most rapidly with advancing age. Corsini and Fasett (1952) reported on 1,072 prisoners admitted to San Quentin. These were divided into three age groups, 15 to 19, 55 to 59, and over 59. The investigators concluded that tests free of speed, vision, and hearing

hold up well with age; verbal tests which include material accumulated throughout life show improvement; and tests involving speed and close attention drop off rapidly.

Although no conclusions can be drawn on present evidence, many writers have contributed data supporting the thesis that a kind of hierarchy exists with respect to mental deterioration. Thus Miles and Miles (1949), who reviewed the literature in this field, state that an information test of intelligence—*i.e.*, a breadth test—"shows increment rather than decrement up to the late forties, with decline after the age of fifty." Lorge (1936) administered several tests to adults aged 20 to 70 years. Among them was the CAVD, a power test, and several speed-power scales such as the Army Alpha and the Otis S-A. He found that age invariably imposed its penalty of declining scores but that some tests fell off more than others. Speed seemed to be most affected by age. When corrections were made to allow for decreased speed in such studies as are under discussion, "no essential decline in intelligence" was evident.

Lorge's findings have been confirmed by Goldfarb (1941), who administered the Otis S-A, the CAVD, and the Wechsler-Bellevue to 168 subjects aged 18 to 65 years. He found no age differences either on the CAVD or on such subtests from the Wechsler as are untimed, but reported significant age differences in all tests involving speed.

More work is in progress in this field. The tentative conclusions of the moment are that tests involving speed show decrements much earlier than breadth or power tests. Since most present-day tests do include a speed factor, it becomes impossible to state with any degree of certainty that pure power or pure breadth tests are unaffected by age. However, it seems probable that, if decline occurs, it begins much later in life and that in normal subjects it is fairly gradual.

EMOTIONAL DEVELOPMENT

Our daily activities are colored by emotions. During the course of a single day we may experience pleasure and annoyance, affection and elation, anger and fear. Emotions are one of the most important aspects of behavior, for, at all ages, they are closely identified with happiness or misery and hence with general welfare. They are important determinants of beliefs, attitudes, interests, and adjustment to the social world.

EMOTIONS AND PHYLOGENESIS

Before discussing emotional development in man, let us look briefly at the changes which accompany phylogenetic ascent. Our comments must be confined to mammals, for there are no good studies on emotional behavior in the lower phyla.

Number of Emotion-provoking Stimuli and Phylogenesis. Certain kinds of stimuli are equally capable of eliciting emotional responses at various phylogenetic levels, among them painful stimuli, sudden noises, sudden loss of support, and restriction of movements. Ascending the scale from rat to cat, dog, chimpanzee, and man, however, the *total number* of effective emotion-provoking stimuli gradually increases (McBride and Hebb, 1948). Perhaps this is best illustrated by fear. Rarely, if ever, is fear elicited in the rat by introducing inanimate objects into the cage, although an avoidance reaction will occur if the object is made to move suddenly. In the dog, excitement and avoidance reactions may be evoked by a number of stationary, inanimate objects such as statuettes of human beings or animals, manikin heads, balloons, or an open umbrella (Melzack, 1952). The chimpanzee shows fear not only of the objects mentioned but also of so many others that it would take a page or more to list them (Hebb and Thompson, 1954). Fear of such things as the following have been described: models of toy animals, small living animals, apparatus or parts of apparatus such as a rope, strangers, the dark, and dead or mutilated bodies. Especially fear-provoking are models of human or chimpanzee heads detached from the bodies. These elicit not only fear but terror in many animals (see Hebb, 1946).

Phylogenetic changes in anger have been well summarized by Hebb and Thompson (1954):

> In the rat, for example, there is little need of such a term as anger for describing the animal's behavior. A rat is aggressive or he is not, and the aggression has about the same pattern in different circumstances. The same seems true of the dog, though occasionally he shows something that may be homologous with the primate's sulking. But with the chimpanzee, it is essential to distinguish anger from chronic malice if the animal is to be handled safely. The peculiarly human patterns of temper tantrum and sulking occur frequently. The causes of aggression are more varied in the dog than in the rat and far more varied in the chimpanzee than in the dog.

A good description of the nature of chimpanzee anger reactions and some of the stimuli which prompt them is given in the following account:

> When the chimpanzee, Dita, in heat, would sit where he could watch her from the next cage Don seemed calm (if not content); but he had a temper tantrum repeatedly whenever she left the outer cage for an inner room where he could not see her. When Mona had a noisy temper tantrum because Pan had stolen a peanut from her, Pan was finally enraged to the point of beating her up. A chimpanzee may be angered by a reproof, by being startled, or by being obliged to look at something unpleasant such as the model of a snake [Hebb, 1949, p. 242].

Duration of Emotional Disturbances and Phylogenesis. In addition to an increase in the number of emotion-producing stimuli, the duration of disturbances increases with phylogenesis. Every animal psychologist has observed that when rats are first placed in a new apparatus they become quite emotional but usually recover within an hour or two. In higher animals, however, the recovery period is longer; it may take several hours or even days for the disturbances to subside. This is well illustrated in a study of porpoises—mammals located above the dog but below the chimpanzee in the phyletic scale—in which the subjects were confronted with a strange, inanimate object which frightened them so they swam away. It took a day or two for this fear to subside (McBride and Hebb, 1948). In chimpanzees, such emotional disturbances may last for several weeks. One investigator (Hebb) cites the case of Fifi, who sulked for 3 weeks when an attendant refused to give her a cup of milk. Only after this long interval would she again accept milk from the person who had once deprived her of it.

These few instances are sufficient to show that phylogenesis is accompanied by (1) an increase in the number of stimuli or situations which arouse emotions and (2) an increase in the duration of an emotional disturbance.

PHYSIOLOGICAL ASPECTS OF EMOTIONAL BEHAVIOR

One of the most extensively explored areas in the field of emotional behavior concerns the nature of physiological changes accompanying emotions. Such external changes as smiling, weeping, screaming, or running away from a fearful situation are readily observable. The changes studied by most investigators, however, are less evident, since they are internal, involving chiefly the autonomic nervous system.

Role of Autonomic Nervous System. Most of the research on the autonomic aspects of emotions concerns fear and anger. In general, such changes reflect sympathetic activities, preparing the organism for increased expenditure of energy and hence for action. Respiration rate is stepped up to provide more oxygen; the heart beats faster, and blood is shunted away from the visceral areas into muscles and brain; and large quantities of adrenaline and glucose pour into the blood stream to raise the energy level of the body. Accompanying these are various changes in the alimentary tract: salivation is inhibited (*e.g.*, in stage fright), while the peristaltic movements of the stomach and intestines and the secretion of gastric juices are suspended, thus halting digestion. The colon and bladder are less readily emptied. Pupils dilate to admit more light, while perspiration and goose pimples may appear on the skin surfaces.

Although these effects of sympathetic action on emotional behavior are more pronounced and therefore more easily recognized than parasympathetic effects, this does not mean that the parasympathetic system is immune to emotional stimuli. Until quite recently, however, it was believed that the parasympathetic remained "silent" during emotionality. Today we know that this is not so. Experimenters have demonstrated that, when emotions are aroused, a simultaneous neural discharge of both sympathetic and parasympathetic systems occurs but that the parasympathetic effects are usually masked by the more dominant sympathetic activities (Gellhorn *et al.*, 1940). Accordingly, whether emotions are pleasant as in affection or unpleasant as in fear or anger, they are nonetheless characterized by autonomic function rather than by either sympathetic or parasympathetic activity alone.

Role of Hypothalamus and Cerebral Cortex. The discussion has so far been concerned primarily with the action of the peripheral autonomic system. However, certain centers in the central nervous system also play a significant role in emotional behavior. Most important are the hypothalamus and the cerebral cortex, which apparently serve as integrators of emotional responses. This is well illustrated by animal experiments. In one study, electrodes, designed as focuses for electrical stimulation, were buried in the hypothalamus of a cat. When the cat had recovered from the necessary surgery, stimulation began. In response to such stimulation the

animal behaved as if it were face to face with a dog, giving full-fledged rage and attack responses (Masserman, 1943).

The important role of the hypothalamus in emotions may be seen even more clearly in an experiment on animals whose hypothalamus had been destroyed. Various emotional responses were exhibited: hissing, lashing of the tail, protrusion of claws, and other signs characteristic of rage in normal cats. However, such reactions appeared only as isolated bits of behavior; there were no integrated attack responses combining erection of hair, protrusion of claws, and forward-directed attack. Supported by other evidence, this indicates that the hypothalamus is an important integrative center for emotions (see Morgan and Stellar, 1950).

Data on the role of the cerebral cortex in emotions also derive chiefly from animal studies. While animals such as cats and dogs, deprived of the cerebral cortex, show typical emotional responses, they differ qualitatively from normal animals in three ways. First, they are hypersensitive to any kind of stimulation, displaying rage at the slightest provocation—even on such slight stimulation as stroking. This suggests that the cortex normally has some restraining influence over subcortical structures such as the hypothalamus and that the restraint is removed when the animal is decorticated. Secondly, the emotional behavior of these subjects lacks direction. The animal does not seem to appreciate the source of a disturbance; if his tail is pinched, for instance, he will direct his attack forward instead of turning around. Evidently absence of the cortex deprives him of the essential perceptual equipment that normally enables him to direct the attack. Thirdly, the timing of reactions is disrupted in these animals. Emotional responses cease as soon as the stimulus is withdrawn—indeed, the experimenter can safely place his hand in the animal's mouth immediately after eliciting a rage response. Such abrupt cessation of emotional response does not occur in normal animals (see Morgan and Stellar, 1950).

Relevant data on human beings have been obtained in studies of anesthesia. Anesthetics usually affect the cerebral cortex before they influence lower structures. Striking changes in a subject's emotional behavior as he is "going under" are noted frequently; he may laugh, cry, or show signs of rage. Such examples indicate that the physiological changes in emotions may involve both the peripheral and central divisions of the nervous system.

Individual Differences in Emotional Sensitivity. Even the casual observer sees great differences among children in the intensity of physiological changes during emotional disturbances. Some children seem to be under continuous tension and fly into temper tantrums easily, while others remain calm in similar situations. Undoubtedly environmental influences, especially training, have a great deal to do with these individual differences. Nevertheless, hereditary factors may also contribute, through such

media as the neuroglandular systems. This possibility is supported by both human and animal data.

Human Studies. Jost and Sontag (1944) investigated such autonomic reactions as skin resistance, pulse and respiration rates, and salivation in a group of children aged 6 to 12 years. Measurements were made over a 3-year period. As might be anticipated, they found considerable differences among children on all such measurements. Perhaps the most interesting feature of the study was the inclusion of six pairs of identical twins. Measurements of the twins and of other children were compared by means of correlation techniques. The autonomic responses of the twins proved to be more closely related than those of either siblings or other children. The correlation coefficients were:

> Identical twins.............. +.43 to +.49 for different pairs
> Siblings.................... +.26 to +.40
> Unrelated children.......... +.02 to +.16

Although these correlations are not high, they are large enough to justify the investigators' conclusion that "what one might call 'autonomic constitution' may be at least partially an inherited characteristic."

Animal Studies. Further support for some genetic basis in emotionality is offered by Hall's (1938) study of selective breeding in rats. Through the use of various tests, he was able to separate fearful from fearless animals. By carefully mating emotional with emotional and fearless with fearless rats for several generations, he eventually obtained a strain which bred true for fearfulness and one which consistently produced fearless offspring (see Chapter 2). Various endocrine glands of the two strains were then examined. The emotional rats had much larger adrenal, pituitary, and thyroid glands than the nonemotional animals (Yeakel and Rhoades, 1941). In the same year, Stockard (1941) reported that dogs of different breeds had different temperamental characteristics, which he related to differences in body build and endocrine structures.

BEGINNINGS OF EMOTIONAL BEHAVIOR

Early Work of Watson. What emotions can the newborn infant experience? Attempts to answer this question date back to the early work of Watson and Morgan (1917), who presented various kinds of stimuli to neonates and noted their reactions. Watson believed that there were three unlearned emotional responses: fear, rage, and love. Fear was evoked by loud sounds or sudden loss of support and was characterized by trembling, catching of breath, random clutching of hands, puckering of lips, and, later, crying. Rage, elicited by restraint of body movements, was characterized by flushing of face, holding of breath, stiffening of body, slashing movements of limbs, and screaming. Lastly, tickling, rocking, and various

tactile stimulations—especially gentle patting of the erogenous zones of the body—evoked a love response characterized by smiling, cooing, and extending the arms. Watson maintained that the complex and diversified emotions of older children and adults result as each of the three unlearned responses becomes conditioned to an increasing number of stimuli encountered during life.

Subsequent Studies. The many investigations of the next three decades failed to corroborate Watson's findings. Sherman and Sherman (1929), who used the same stimuli as Watson—loud noises, dropping the infants, restricting body movements, and stimulating erogenous zones—were unable to substantiate his theory of three unlearned responses. In discussing their findings, they state:

> Any form of sudden stimulation such as dropping, loud noises, restraint, pain or a rush of air on the face, produces in the young infant aimless activity of most of the musculature, accompanied by crying. The stimuli must be sufficiently strong, however, to produce a reaction. When an infant below four or five days of age is dropped one or two feet it frequently shows no perceptible response, except for vague movements of the arms and legs. The younger the infant the stronger must be the stimulus. This is also true for the so-called "pleasurable" stimuli such as stroking or petting to which many newborn infants show no overt reaction [p. 145].

Thus, instead of obtaining any constant pattern of response as reported by Watson, Sherman and Sherman found only a generalized "aimless activity of most of the musculature" in all cases, regardless of the stimulus used.

Other studies support these findings. Irwin (1932), for example, whose sample included 24 infants, tried dropping them a distance of 2 ft. before catching them again. In only 2 out of 85 cases did the subjects either tremble or cry after this sudden loss of support, and 12 per cent of the cases showed no overt response whatever. Loud noises yielded equally negative results, and what responses did appear were described as "mass activity." In another investigation, 66 infants were tested by holding their arms against the body—the restraint stimulus supposed to evoke anger. In over 75 per cent of the cases, the infants remained motionless (Pratt *et al.*, 1930). Finally, Taylor (1934) made an attempt to duplicate as far as possible the conditions of Watson's study. On the basis of his very careful observations, he concluded that no constant response pattern followed such stimuli as loud noises, sudden dropping, or restraint of movements.   '

Accordingly, it seems that emotional behavior in infants is characterized by undifferentiated, generalized activity of the body musculature rather than by response patterns specific to different stimuli.

DEVELOPMENT OF EMOTIONAL BEHAVIOR

Although the neonate exhibits no specific emotional patterns distinguishable to observers, older children give clear evidence of varied behavior which may properly be called fear, anger, affection, elation, jealousy, and so on. When, then, do these emotions differentiate and what is their course of development?

Bridges's Study. Undoubtedly the most comprehensive observations of emotional development were made by Bridges (1932), who studied babies ranging in age from birth to 2 years in a foundling home. In line with find-
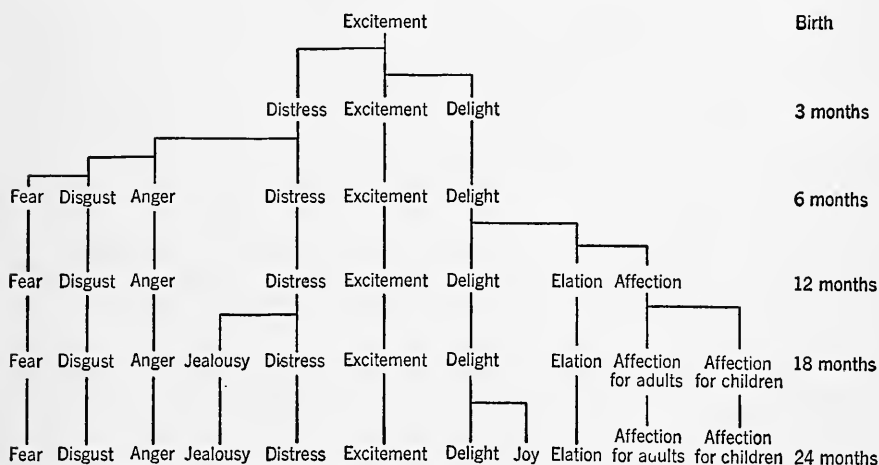
Fig. 87. Bridges's schema of emotional development during infancy. The ages of emotional differentiation are only approximate. (*After Bridges. From L. Carmichael (Ed.), Manual of child psychology. New York: Wiley, 1946. P. 755. By permission of the publishers.*)

ings discussed earlier, Bridges noted that neonates responded to any kind of emotional stimuli with an undifferentiated excitement evidenced by uncoordinated skeletal-visceral responses. From this general state, various emotions began to differentiate as maturation and learning advanced. First to emerge during the third month were distress and delight. Distress was characterized by crying, checked breath, and muscular tension, while delight was evidenced by smiling, gurgling, and muscular relaxation. By the sixth month, distress had further differentiated into anger, disgust, and fear. Some time later, elation and affection for people branched off from the delight stem. By 18 months, jealousy had emerged from the distressful stem, and affection for people subdivided into affection for adults and affection for children. Finally, between the ages of 18 and 24 months, joy became distinct from elation and affection. Bridges's conception of these various steps is shown in Fig. 87.

On the basis of work with older children, Bridges (1930) maintains that by the age of 5 years other emotions such as envy, disappointment, anxiety, and shame branch out from the distressful stem, while parental affection and hope differentiate from the delight stem.

Evidence Supporting Bridges's Theory. In general, Bridges's theory has received support from several sources. Blatz and Millichamp (1935), for example, who studied five children between the ages of 1 month and 2 years, reported a genetic sequence for 18 emotional responses. Each type of response seemed to emerge at a certain age, but the expression or form of response changed continuously as age advanced, becoming progressively less diffuse and more specific to certain situations. Bühler (1930), too, noted a progressive differentiation of emotions with increasing age. Neither Blatz nor Bühler agrees with Bridges on the precise ages at which each of the emotions differentiates from the parent stem. However, this difference is minor, since all agree regarding the developmental sequence of emotional growth and regarding the major point that the adult repertory gradually differentiates out of one or relatively few responses present at birth.

Animal Support. Some interesting data on animals have recently furnished additional support to Bridges's theory of emotional differentiation. Using dogs as subjects, Melzack (1952) found that the earliest response of these animals to a variety of emotional stimuli was general excitement. After weaning, the puppies were taken away from their mothers and placed in cages, two to a cage, where they were reared in isolation for 8 months. Cages were so arranged that the puppies could not see any human beings or environmental objects outside the cage. They were not handled by the experimenter at any time. At the close of the isolation period they were tested for reactions to various animate and inanimate objects.

One of the most interesting findings was the presence of a generalized excitement similar to that described by Bridges for human neonates. This was seen most clearly in the dogs' response to a stationary white rabbit. The dogs would approach the rabbit, withdraw, advance, and retreat again, evidencing ambivalent behavior, then madly circle the room only to stop and repeat the performance. Similar reactions were evoked by such diverse stimuli as a chimpanzee skull, a balloon being inflated, and a moving toy car. Testing was continued for 2 weeks. Toward the end of the test period, the dogs exhibited less of the general excitement and began to show definite avoidance—the first sign of differentiation. Nine months later, the same dogs were retested. At that time little of the generalized excitement appeared; the animals immediately showed avoidance of the rabbit, skulls, balloon, and car and occasionally exhibited the second stage of differentiation by aggressively attacking the objects.

Characteristics of Emotions and Emotional Responses at Various Ages.
Children's emotions differ from those of adults. According to Hurlock
(1950), they are characterized by briefness, lack of graded intensities,
transitoriness, and frequency. Each of these will be discussed in turn.

Children's emotions last for only a few minutes. Since they are overtly
and often explosively expressed, the child's "system is rapidly cleared" in
sharp contrast to the prolonged reactions of adults. As the child grows
older, he learns to restrain emotional outbursts in the interests of social
approval. By adolescence, the eruptions have almost disappeared, while
prolonged reactions known as "moods" tend to replace them. Restrained
anger may take the form of sulking, while repressed fears may be evi-
denced in jumpiness or timidity.

The second characteristic of children's emotions is a lack of gradation
of intensity. A trivial stimulus produces just as great an outburst as a
more serious one, especially in joy-, fear-, or anger-provoking situations.
With advancing age, responses become more controlled and more appro-
priate to the stimulus. Again, the agency responsible for the change seems
to be social approval. To win the approbation of other children and adults,
the youngster learns to curb emotions by inhibiting the earlier intense
outbursts and ignoring minor stimuli. By adolescence, he realizes that
exhibitions of temper and other extremes are considered infantile.

It is difficult for adults to understand the transitory nature of the young
child's emotions which shift quickly from tears to laughter and from
frowns to smiles. An analogous, if not similar, transitoriness appears in
early adolescence, as the teen-ager plunges from the pinnacle of joy to the
depths of gloom or despair in the same day. There is a distinction, how-
ever, for the transitoriness of the child's emotions depends more on his
own physical condition, while that of the adolescent is influenced largely
by environmental conditions and by self-evaluations.

A fourth characteristic of children's emotions is their frequency.
Screams of fear or anger, gales of laughter, and shouts of joy generously
punctuate the child's day. He soon learns that social disapproval follows
his numerous exuberant outbursts, however, and that he must adjust to
emotion-provoking situations in less boisterous ways. Accordingly, there
is a gradual decrease in the frequency of overt responses as the child grows
older.

Inhibitions of Overt Expressions. Probably the most conspicuous age
change in emotional reactions is the gradual inhibition of the overt signs
of emotionality. Adults are usually able to hide their feelings—indeed, the
epitome of poise frequently seems to involve an ability to inhibit all spon-
taneous expression. This is not the case with young children. They are not
in the least reluctant to kick, bite, scream, or, if the emotion is a pleasant
one, embrace the person concerned. While such gross overt expressions are

less frequent among older children, they continue to show emotionality in such things as restlessness, general tension, timidity or shyness, generalized anxiety, specific fears, nervous habits, and speech difficulties. During the teens, overt responses continue to wane so that by late adolescence or early adulthood feelings and emotions are usually well hidden.

ROLE OF MATURATION AND LEARNING

As with most kinds of behavior, both maturation and learning play important roles in the development of emotional-response patterns. In certain cases, their separate roles can be seen quite clearly; in most situations, however, the interrelationships are so complex as to defy analysis.

Role of Maturation. Undoubtedly the best way to discover the importance of maturation would be to study children reared in complete isolation from the time of birth. This is obviously impossible. An approximation of such a condition is attained through study of individuals born deaf and blind. These individuals have had no opportunity to learn emotional behavior through imitation; they have never seen anyone clench a fist in anger, have never witnessed the various facial expressions accompanying emotions, and have never heard shouts of laughter or seen how laughter is made. Such subjects are rare and reports on deaf-blind children infrequent. Goodenough (1932), however, had an opportunity to study the emotional behavior of a 10-year-old girl, deaf and blind from birth. The child was subjected to a variety of emotion-provoking stimuli, and her reactions were permanently recorded on film.

The deaf-blind subject exhibited temper tantrums, anger, timidity, joy, resentment, and other emotions similar to those of normal children despite the fact that with her physical handicaps she received neither visual nor auditory stimuli. Goodenough concluded that many of the overt characteristics of emotions are unlearned and furthermore that "among persons with normal sensory equipment the original reaction patterns may become so overlaid with a veneer of socially accepted forms of behavior that it is difficult to distinguish the native from the acquired."

Blind and Seeing Children. Another investigator compared the facial expressions of 26 blind and 29 seeing children, aged 7 weeks to 13 years (Thompson, 1941). He, too, used a photographic method, recording the expressions of the subjects in various emotionally toned situations. Both blind and seeing children exhibited similar response patterns for anger, sulkiness, annoyance, and sadness, but the expressions were more uniform in the seeing children. Older blind children showed less facial expression in smiling. No typical response to fear was evidenced by the blind subjects, but Thompson believes that the stimuli used may have been inadequate to elicit fear. He concludes that since the blind show response patterns similar to those of seeing children of comparable age, emotional expres-

sions "seem to be maturational since there is no other obvious way in which they could have been brought about." Age differences emerged in both blind and seeing subjects.

Growth of Fears. Finally, let us mention an extremely interesting study by Jones and Jones (1928), who observed the reactions of 51 children and 90 adults confronted by and asked to handle a snake. Children under 2 years of age evidenced no fear whatever and handled the snakes as if they were ordinary playthings; between 3 and 3.5 years, they showed caution and great attentiveness to the snake; after the age of 4, definite fear behavior appeared; in adults, the fear was more pronounced. These investigators carefully point out that the children could not have learned to fear snakes either as a result of stories heard or read or in consequence of previous contact with such animals. They maintain that the fear reaction emerged gradually because of a general physiological development of the nervous and sensory systems, promoting keener perception of new things and greater intellectual powers.

The arousal of fear depends not only upon situational changes, but also upon the individual's general level of development . . . As a child develops, his intelligence innately matures, and his perceptions become enriched through experience. New things startle him because of his keener perception of the fact that they are new and unusual . . . Fear arises when we know enough to recognize the potential danger in a stimulus, but have not advanced to the point of complete comprehension and control of the changing situation [pp. 142–143].

This developmental picture of the growth of fears is supported by Hebb's (1949) investigation of chimpanzees. Hebb observed that many adult chimpanzees are terrified by various objects presented for the first time, although young animals evidence no such terror. He summarizes his results as follows:

. . . some of the chimpanzees of the Yerkes colony might have a paroxysm of terror at being shown a model of a human or chimpanzee head detached from the body; young infants showed no fear, increasing excitement was evident in the older (half-grown) animals, and those adults that were not frankly terrified were still considerably excited. These individual differences among adults, and the difference of response at different ages, are quite like the human differences in attitude toward snakes, the frequency and strength of fear increasing with age . . . *The increase fits in with the conception that many fears depend on some degree of intellectual development* [p. 243]. (Italics added.)

Role of Learning. That learning plays a role in the development of emotional behavior becomes evident if we note the nature of emotional expressions in individuals of different cultures. It is well illustrated in the Chinese, among whom some expressions are similar to ours while others are quite different. Clapping of hands is a sign of happiness or pleasure in our culture, for example, but among the Chinese it indicates worry or

disappointment. Again, we show surprise by elevating the eyebrows and widening the eyes, whereas the Chinese do so by sticking out their tongues (Klineberg, 1938).

Even within our own culture, the role of learning may be seen when we compare the kinds of fears prevalent in children and parents. Hagman (1932), who observed the fears of preschool children and their mothers, found that the fears of the two generations correlated $+.67$. He concluded that children learned to fear certain situations by watching their mothers' reactions in similar situations. If the mother was afraid of lightning, of the dark, or of certain animals, the child was quite likely to be afraid, too.

The above examples illustrate imitative learning; however, emotional patterns may also result from conditioning. The classic example of the acquisition of emotional reactions through conditioning is unquestionably Watson and Raynor's (1920) investigation of the baby, Albert. Albert, who was 9 months old, had no fear of such objects as rats, rabbits, dogs, or balls of cotton wool, but he showed unmistakable signs of fear when a loud sound was produced unexpectedly. The experimenters induced fear of a rat in the following way. A rat was placed in front of little Albert. As he was about to touch it, a loud sound was made by striking an iron bar behind him. Albert was startled and fell forward. When the procedure was repeated a second time, he began to whimper. A week later, five further presentations of rat coupled with loud noise were made, and following this the rat was presented alone. No longer did Albert reach for the rat. Instead he shrank back at the sight of it, cried, and exhibited typical symptoms of fear. He had learned by association, or conditioning, to fear an object that had aroused no such emotion earlier. Furthermore, his new fear extended to other furry objects such as rabbits, dogs, fur coats, and even a ball of cotton wool. Objects such as wooden blocks or toys that bore no resemblance to the rat failed to produce any fear response. Thus we see that fear which is at first specific to one object may soon be generalized to a variety of similar objects.

A further illustration of such generalization is provided in a study by Jersild and Holmes (1935a). They found that fear of radios grew out of fright at the sound of applause on the radio; fear of being confined in a small space developed from fear of elevators; fear that the mother would die developed from dread of old, wrinkled people; and fear of going out alone grew out of stories about murderers and kidnapers.

EMOTIONAL CHANGES THROUGHOUT THE LIFE SPAN

Bridges's Differentiation-Constriction Theory. Bridges (Banham, 1951) extended her theory of early differentiation of emotions to include adult-

hood and senescence. The later theory is schematically illustrated in Table 22. The left-hand side of the table, showing differentiation, has already been discussed. Adulthood, represented in mid-line of Table 22, is characterized by maximum differentiation, sensitivity to emotional cues, and a peak of control of emotional responses. According to this theory, emotional behavior is at its most adaptive level during maturity, when "some emotion may be expressed in visceral and behavioral response, but not too much, and none is wasted in useless movement or tension as in the case of young children or emotionally immature persons . . . Behavior responses are most varied, but purposefully and adaptively related to the stimulating event, to individual and social needs."

As age advances, the individual becomes less and less responsive to emotional stimuli. Reactions continue to be specific to a situation but are less varied and less appropriate than in adulthood—indeed, they may become inappropriate because they are too specific and pertain to only a part of a solution rather than the whole. Children's emotional reactions may be inappropriate because they lack discrimination, because they are of an "all-or-none" nature, or because of hyperexuberance; nevertheless, they respond to the total situation. On the other hand, senescents' responses may be quite as inappropriate but for different reasons: they are neither comprehensive enough nor varied enough to deal with new situations and concern a part of the stimuli rather than the whole. Whereas children's responses are fluid in the extreme, senescents' reactions are rigid and perseverant.

According to Bridges's schema, then, childhood and senescence represent opposite poles of the continuum shown in Table 22. One extreme is characterized by a differentiation from general excitement; the other, by constriction resulting in apathy and passivity. Although considerable evidence supports a differentiation theory, so far there are few data on emotions in old age. The few available will be examined presently. More research is badly needed in this area.

Willoughby's Studies. The only experimental evidence on emotional changes covering most of the life span was assembled by Willoughby (1935, 1936–1937), who used a questionnaire technique, the Thurstone Personality Schedule. In the first of these studies, he gave the questionnaire to 500 single women, 325 single men, and 275 married couples all ranging in age from 15 to 75 years. He found a sex difference extending over this entire age span. Women were significantly more responsive to emotional stimuli than men. The scores of males showed little or no age difference, but those of women fluctuated from time to time.

The variation in scores is shown more easily in the second study of 500 women aged 15 to 75. Subjects were of superior educational and socioeconomic status and of urban background. The questionnaire used was

TABLE 22. SCHEMATIC REPRESENTATION OF A GENETIC THEORY OF LIFE-SPAN EMOTIONAL CHANGES*

INFANCY	MATURITY	OLD AGE
Undifferentiated response	Mature emotional sensitivity and control	Constricted response
Random behavior	Maximum differentiation of response and aesthetic feeling	Perseverative behavior
Processes of differentiation and integration		Processes of consolidation and some disintegration

Excitement

Distress { Anxiety, Fear, Shame, Anger, Disgust, Jealousy, Disappointment, Restlessness, Uneasiness } → Grief, Worry, Self-pity, Guilt feelings, Querulousness, Irritability, Boredom } Depression } Apathy and Passivity

Delight { Joy, Elation, Hopeful anticipation, Affection, Sex love } → Mystical ecstasy, Possessive satisfaction, Benevolence, Gustatory sensuousness } Content } Apathy and Passivity

* From Banham, K. M. Senescence and the emotions: a genetic theory. *J. genet. Psychol.*, 1951, **78**, 180. Quoted by permission of the Journal Press.

similar to that of the first study, with potential scores ranging from 0 to 160, the high scores indicating great emotionality. The findings are graphically illustrated in Fig. 88. Contrary to popular notions, adolescents were less emotional than adults. Emotionality increased through early adulthood, fluctuated slightly, decreased around the menopause, and increased again in later maturity. Unfortunately, the number of cases over 60 years of age was too small to give any adequate picture of old age. Perhaps the most dramatic finding was that the two periods usually regarded as "emotionally unstable"—adolescence and the menopause—were in reality the most stable, according to this study. More evidence is needed, however, before this finding can be accepted as fact (see also Chapter 15). Wil-
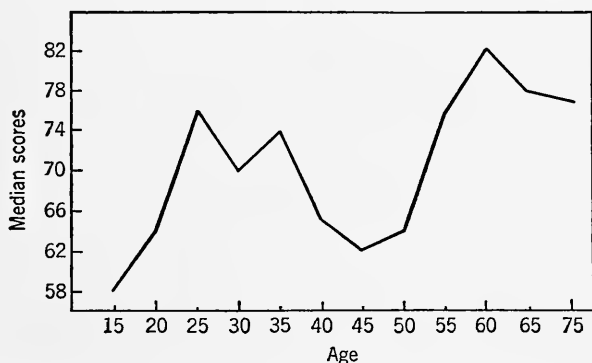
FIG. 88. Changes in emotionality with age. High scores indicate great emotionality. (*From Willoughby, R. R. The emotionality of spinsters. Character & Pers., 1936–1937, 5, 217. By permission of the publishers.*)

loughby attributed the initial rise during the teens and early 20's to increasing tensions over "the life problems of sexual adjustment," and believed that the low level around the menopause "may reflect lessening of sexual tensions, relative remoteness of sexual possibilities, maximum earning power and relative remoteness of incapacitating old age." The second rise, he thinks, may reflect adjustment to old age.

Emotionality in Later Life. Studies of emotional changes in later life are rare; the few available are based on either questionnaire or Rorschach techniques.

Studies Using Questionnaires. In examining Fig. 88 based on Willoughby's data, it was noted that the 50's were marked by an upswing in emotional responsiveness. Some support for this finding is offered by Brožek (1952), who distributed questionnaires to 200 business and professional men, aged 46 to 56, and to a second group of 119 younger males, aged 18 to 26 years. The questionnaire contained such items as the following: (1) My muscles often feel tight and tense. (2) I have never "blown my top." (3) I have never been easily moved to tears. From such items as

differentiated the older from the younger men, Brožek built the following composite picture of the older subjects:

> Throughout, the older men tend to evidence a greater amount of tension and a greater responsiveness to emotional stimuli. They were less calm and easy-going than the younger men. Their muscles often tense and their stomach feels at times like it is in knots. They are more easily hurt by criticism but they get over it more quickly. They are more easily moved to tears but on the whole they are more reserved in the expression of their feelings and fluctuate less in their mood. They are likely to feel angry inside and keep their tensions well covered up. Their intake of coffee, tobacco and alcohol is higher. There was no consistent difference in the tendency to obsessive ideas.

Thus, this group of middle-aged business and professional men are tense, are responsive to emotional stimuli, are sensitive to criticism, fluctuate little in mood, and keep overt manifestations of emotions well hidden. Whether the same pattern exists in nonbusiness and nonprofessional men is a moot question. It seems plausible that with less competitive pressure tensions might also decrease.

Studies Based on Rorschach Tests. Another look at Fig. 88 reveals that after the age of 60 emotionality tends to decrease. Although Willoughby's sample was very small at this age level, his findings are supported by four recent reports based on Rorschach tests of elderly people. Earliest of these was Klopfer's (1946) investigation of 50 persons between the ages of 62 and 93 years. His subjects showed a low level of responsiveness to the "finer emotional nuances in their environment" and were, in general, unable to make use of their inner resources. Some loosening of intellectual ties to reality also appeared.

Prados and Fried (1947) reported on 35 subjects aged 50 to 80 years. According to their analysis, the capacity for emotional responsiveness became quite shallow, and very little inner conflict was evidenced. This shallowness of responsiveness was confirmed by two other investigators (Chesrow *et al.*, 1949; Grossman *et al.*, 1951). After surveying the literature in this area, Gilbert (1952) concludes that elderly people exhibit "reduced and shallow emotional responsiveness, efficiency and productivity, little inner conflict, reduced control of instinctual demands, constriction, impotence and a recurrence of the primitive manifestations of childhood."

Fear

Emotions and emotional responses have been discussed so far only in general terms. Let us now look more closely at the evidence available on such specific emotions as fear, anger, and jealousy, paying particular attention to age changes. We shall note that most of the work has been done with children, less with adolescents, and scarcely any on the specific emotions in maturity and old age.

Origin of Fears. It has already been pointed out that both maturation and learning contribute to the development of fears. For example, young children under the age of 4 had little fear of snakes, but older children showed fear. This was interpreted to mean that physical and sensory structures had to mature before children became acutely sensitive to newness or to the potential dangers inherent in certain unaccustomed objects. It was demonstrated, too, that many fears are learned, either through imitation or through conditioning. Now some further aspects of this unpleasant emotion will be examined.

Metabolic Disturbances and Fears. One source of fears, often overlooked, is found in metabolic disturbances (Hebb, 1949). Around puberty or the menopause, for example, endocrine disturbances frequently give rise to fears and anxieties. It is also well established that nutritional deficiencies may produce tenseness, "nervousness," etc. Perhaps the clearest illustration is seen in pellagra, a condition brought about through lack of one of the B-complex vitamins, niacin. According to clinical evidence, patients suffering from a severe case of pellagra have pronounced fears of relatives, friends, and a host of hallucinatory creatures. Careful studies, in which controls have ruled out the possibility of psychological influences, have demonstrated that such fears may be dramatically eliminated through administration of niacin (Spies *et al.*, 1938). Accordingly, the psychotic fears present in pellagra cases reflect metabolic disturbances alone.

Characteristics of Fear Stimuli. Although children may be frightened of many things, for maximum effectiveness fear stimuli generally must appear in a certain context. One most important characteristic of fear-provoking stimuli is suddenness or abruptness. English (1929) demonstrated that fear is not aroused by a loud noise but by a sudden noise; for example, when auditory stimulation is built up gradually, no fear results. Another characteristic is unexpectedness. Preschool children exhibit no fear of such objects as stuffed animals, false faces, or slimy or furry creatures unless these objects appear before them unexpectedly. The unexpected leap of a frog may cause fear (Jones, 1933). Hence it seems that fear is not elicited by the stimulus per se so much as by the suddenness and the surprise element involved in the presentation.

Another peculiarity of fear-provoking stimuli is novelty of certain properties as opposed to familiarity of other features, "the divergence of the object avoided from a familiar group of objects, while still having enough of their properties to fall within the same class" (Hebb, 1949). Dozens of everyday incidents illustrate this characteristic. A child may be afraid of familiar people dressed in unfamiliar clothes; an infant fails to recognize his father when he wears a hat, or screams when his nurse wears a street costume instead of the usual uniform; even chimpanzees that show no fear of a familiar attendant become emotionally disturbed when the attendant

dons someone else's coat. Neonates are not shy of strangers until such time as they have learned to identify family members and hence are able to discriminate between the familiar and the unfamiliar.

Changes in Fears during Childhood. The earliest fears are aroused by loss of support, falling, and loud noises. We do not know precisely when such stimuli first elicit fear, but according to Bridges and others they probably become effective sometime during the first half-year. Fears specific to events, objects, persons, and surroundings differentiate later.
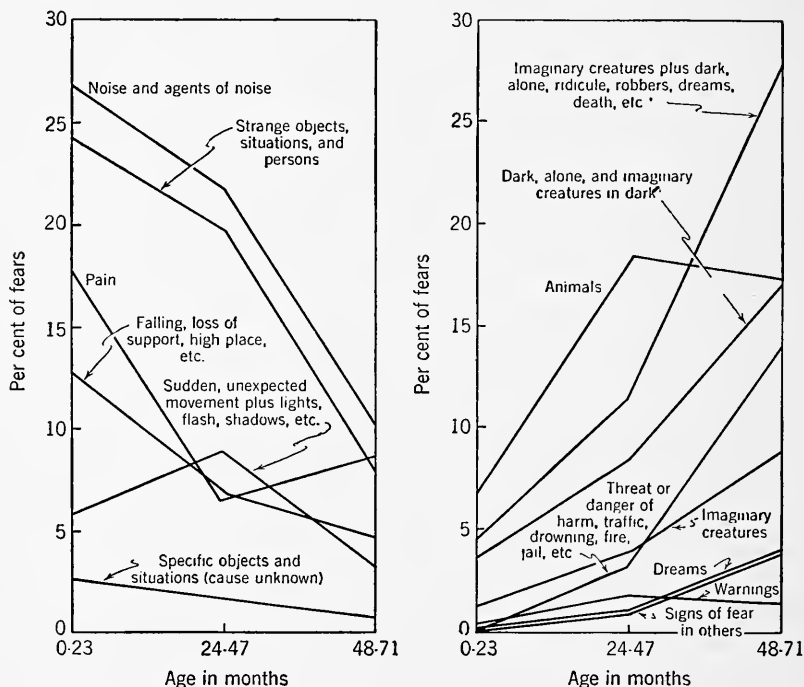
Fig. 89. Age changes in the nature of fears during the first 6 years of life. (*After Jersild and Holmes. From L. Carmichael (Ed.), Manual of child psychology. New York: Wiley, 1946. P. 763. By permission of the publishers.*)

Some of the age changes in fears during the first 6 years are shown in Fig. 89. For the first 2 years, children are afraid of noises and agents associated with noises; strange objects, situations, or persons; painful shocks; falling; loss of support; and elevated positions. These so-called concrete fears decline rapidly after the age of 2 and have practically disappeared by middle childhood. Although present in 2-year-olds, fear of animals does not reach a peak until the age of 4 years, declining thereafter.

As intellectual capacities and especially imagination develop, children begin to anticipate the future. Fears reflect this change, for they too begin to contain elements of remote imaginary dangers and misfortunes. As

shown in the right-hand diagram of Fig. 89, beginning at the age of 2 children become increasingly afraid of the dark, imaginary creatures in the dark, robbers, matters concerned with death and solitude, fire, drowning, traffic, jail, and other sources of physical injury or destruction. Accordingly, preschool years are characterized by a decrease in fears of a concrete or tangible nature and an increase of imaginative fears (Jersild and Holmes, 1935b).

Some notion of the changes during middle childhood is provided by Jersild et al. (1933). Using questionnaire techniques, they found that the greatest incidence of fears at this time surrounded imaginary, mysterious, and supernatural events and potential harm from sources which had never actually threatened the children. Second in rank order was a fear of animals read about but never encountered in real life. Concrete fears of lightning, thunder, high places, and strange objects or persons persisted throughout middle childhood but were much less frequent than imaginary fears. In summary, it might be said that fears of an imaginary-mysterious character, present by the age of 5 or 6, tend to increase and to be maintained through middle childhood, gradually replacing the concrete fears.

Fears of Adolescence and Adulthood. Research on the nature of post-childhood fears is almost negligible. Only one extensive study has been attempted (Wake, 1950). Wake compared a group of early adolescents aged 11 to 16 with a group of university students between 18 and 24 years of age, subjecting them to extensive interviews followed by presentation of a comprehensive list on which they checked their own fears. Analyses were made according to both age and sex.

According to this survey, the principal fears of adolescent boys are of a social nature: fear of exclusion from social gatherings or committing a *faux pas* if present, of performing in front of a group, of being ridiculed, and of talking to certain people. This category included 22 per cent of all fears mentioned. Second in frequency were fears of animals (14.7 per cent), especially of snakes but also of insects, horses, and marine animals. Third in incidence were fears of real or imaginary accidents (8.4 per cent) such as potential injury or death from traffic, sinking ships or aircraft crashes, as well as witnessing such injury to other persons or animals. When we compare the fears of early adolescent boys with those of college men, we find that the social fears not only persist but increase to account for 26.4 per cent of all reported fears in subjects 18 to 24 years old. On the other hand, fears of animals and of accidents drop out to be replaced by sexual fears (9.9 per cent) and fears of authority (8.8 per cent). Sexual fears revolve around consequences of intercourse such as pregnancy, venereal disease, and discovery; fears of authority include dread of parental criticisms and of disappointing parents by failure in school or work.

The highest incidence of fears in adolescent girls concerns animals (21.1 per cent). Although fear of snakes and horses is most common, 11 different objects received frequent mention. Social fears rank second, with 13.6 per cent incidence, while real or imaginary accidents account for 11.6 per cent. Thus the main sex difference of the early teens is the prevalence of animal fears in girls. In the adult females, social fears come strongly to the fore (29.7 per cent), animal fears persist but with less frequency (15.5 per cent), and sexual fears have emerged into third place (10.0 per cent). When the findings are considered as a whole, it seems that during the transition from childhood to adolescence concrete fears are replaced by social fears, and from adolescence to adulthood these social fears become intensified, while sexual fears also emerge.

Summary of Developmental Changes in Fears. Wake (1950) conveniently summarizes the responses of several age groups so as to provide a developmental picture of fear from infancy to adulthood. This summary is shown in Table 23. Fears were classified according to three major cate-

TABLE 23. AGE CHANGES IN TYPES OF FEARS BETWEEN INFANCY AND ADULTHOOD*

Types of fears	Jersild's boys and girls, ages 0–8	Jersild's subjects, ages 5–12		Wake's subjects, ages 11–16		Wake's subjects, ages 18–24	
		Boys	Girls	Boys	Girls	Men	Women
Concrete, per cent.........	83.8	45.1	40.0	56.2	59.4	50.8	56.4
Personal inadequacies, per cent....................	4.7	4.6	5.5	28.8	21.6	43.1	28.2
Imaginative, per cent.......	11.4	50.2	54.5	13.6	16.2	6.1	15.0

* From Wake, F. R. Changes in fear with age. Doctor's dissertation, McGill University, 1950. P. 44.

gories: concrete, personal inadequacy, and imaginative. In the concrete category Wake includes fears of animals; strange objects, persons, and situations; noises; falling; accidents; etc. Personal inadequacies involve such things as fear of personal failure; performing in public; sexual inadequacies; loss of property, friends, relatives; and so on. The imaginative fears include dread of the supernatural and mysterious, of being alone, of imaginary situations and creatures. Up to the age of 8 years, well over 80 per cent of fears are concrete; from 8 to 12 years, the concrete type shows considerable decline, probably because the child becomes master of his own body to a greater degree and, as judgment increases, becomes better able to control concrete situations. What concrete fears remain by adolescence seem to persist into adulthood.

On the other hand, fears of inadequacies are almost totally absent prior to the age of 12. During adolescence there is a sudden and large increase in this type of fear, followed by a further increase in adulthood, especially among males. Imaginative fears are frequent between the ages of 5 and 12 years, probably as the awareness of potential dangers increases and contacts with literature, radio, and movies expand. By adolescence, such imaginative fears have begun to decline, perhaps because of increasing social pressure and realism. This decline continues into adulthood.

Worries

There is a considerable body of knowledge on what is known as worry. Existing literature, however, makes no clear distinction between worry and fear. Hurlock (1950), for example, considers worry as an imaginary form of fear—a type of fear which is not elicited directly by some specific environmental stimulus such as animals or objects but rather by imagining the consequence of a certain situation such as failure to do one's homework or the death of a parent. According to her definition, many of the imaginary fears already discussed would be classified as worries. However, we need not be concerned with such differences; under worries, we shall discuss studies classed as worries by their respective investigators. Without exception, these studies have employed the questionnaire technique.

Worries during Childhood. We would scarcely expect to find worries among the brief and transitory emotions of young children. Accordingly, studies in this area begin with middle childhood. Pintner and Levy (1940) administered a "worry" inventory to 540 children in grades 5 and 6 in New York City. They found that both sexes worried most about family and school situations. Worry over family affairs centered around possible illness and overwork of parents; in school affairs, they revolved around failure in examinations, poor report cards, and scoldings. Worries about health, personal inadequacies, and economic problems ranked next.

A second survey by Jersild et al. (1941) listed the worries of 1,100 children, also in grades 5 and 6 in New York City. The greatest sources of worry of these subjects were failure in school, scoldings at home or school, and poor report cards. Most prominent among the out-of-school worries was concern about ghosts, kidnapers, nightmares, death, and meeting strange people. On the whole, worries relating to school situations were more prevalent than out-of-school worries.

A comparison of the two studies indicates that most of the worries mentioned are common to all elementary-school children. The absence or low incidence of worries concerning overwork of parents and economic affairs in one group as opposed to the other is doubtless due to the sampling of different economic areas.

Worries during Adolescence and Early Adulthood. A recent and excellent study of 5,000 students gives us a good idea of changing worries from grade 6 through college. Findings of this extensive investigation are shown in Fig. 90. Grade-school students worried about improbable events such as fire, holdups, and death. These worries declined rapidly, to be replaced by worries of socioeconomic character. As high school merged into college, concern over examinations, ability, work, money, appearance, and morals increased. Certain sex differences appear in Fig. 90. Worries of a social nature (appearance, clothes, self-consciousness, and
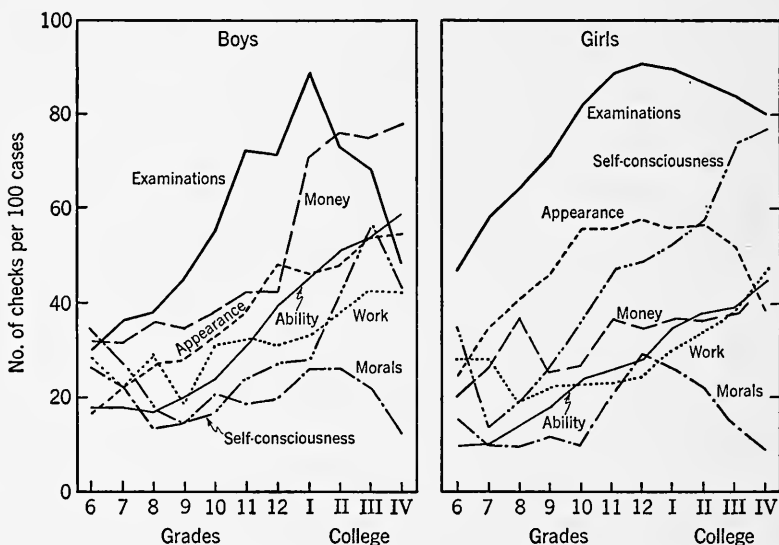
FIG. 90. Age trends in worries during adolescence and early adulthood. (*Based on unpublished data of Pressey. From Kuhlen, R. G.   The psychology of adolescent development. New York: Harper, 1952a. P. 273. By permission of the publishers.*)

morals) emerge earlier and are more frequent in females than in males. On the other hand, worries of an economic character (work, money, and ability) emerge earlier and show higher incidence in males. This reflects (1) the earlier physical maturation of females and (2) the stress which our culture places on the economic responsibility of males.

Worries during Maturity. Data are lacking beyond early adulthood in this area as well as in many others. Kerr *et al.* (1949) submitted one interesting report, but it is based on an unrepresentative group and is of questionable validity since it involves retrospection. Kerr mailed questionnaires to 250 American psychologists and received replies from 103, ranging in age from 46 to 81 years. These subjects gave retrospective reports of worries at various earlier ages as well as of their present concerns. Over half of the respondents recalled that appearance and sexual morality

were sources of worry during their 20's; 91 per cent reported a preponderance of financial and other economic worries during the 30's; in the 40's, the most frequent source was giving up the important hopes and ambitions of early life and marital difficulties. No generalizations can be made on the few cases over the age of 50.

While this study shows a logical and plausible shift with age, it must be remembered that the group was not representative of the general population, nor is there any guarantee that the 103 respondents were representative of either the sample selected or psychologists as a group. Possibly the 147 who had few (or extensive) worries ignored the questionnaire.

Worries in Old Age. Morgan (1937) used the interview technique to explore the nature of the worries of 381 men and women over 70 years of age, residents of various cities in New York State. The subjects were not institutionalized but continued to live in the general community, 74 per cent in their own homes and the remainder in other homes not directly supervised by relatives. They belonged to the working class, and their education level was average for their generation. Percentage incidence of their more frequent worries was as follows:

Financial worries and dependence	48.4
Concern for spouse or family	20.9
Poor health and physical dependence	18.4
Inability to work	6.0
Family relationships, estrangements, etc	5.0
Death	1.3

It is evident that the major source of worry is financial; concern for family and health rank second; worries over approaching death are rare.

Anger

Most of the research on anger, like that on fear, concerns childhood and adolescence. Data on adult years are negligible; any work on these ages relates to annoyances—mild irritations much less violent and unpleasant than anger.

Origins of Anger. According to Bridges (see Fig. 87), anger differentiates from distress sometime around the sixth month. Both maturation and learning are involved. Dennis (1940b), who reviewed the literature on infant reactions to restraint, believes that both initial appearance and later occurrence of anger are related to maturation and emerge spontaneously regardless of differences in early experience and training. Environment, however, may partly determine what situations give rise to anger at later ages and how anger will be overtly expressed or whether it will be inhibited.

Causes of Anger. During early childhood, anger occurs more frequently than other emotions, probably because so many things interfere with the

child's activities and so many restraints are introduced. Moreover, children learn very quickly that anger is a useful attention-getting device and that it often procures what is otherwise denied.

Numerous situations provoke anger in young children. Barker *et al.* (1941) found that children responded to frustration by becoming angry; Goodenough (1931) reported anger responses when the environment was so poorly defined that the child felt insecure, and she also reported that outbursts were more frequent among children in poor health; Burton (1942) observed anger when children tired of a certain activity and reached a "satiation-point"; Jones (cited by Watson, 1925), who studied children aged 16 months to 3 years, reported over 100 causes of anger common in that age range. Most frequent were (1) having to sit on the toilet chair, (2) being deprived of property, (3) having the face washed, (4) being left alone, (5) adult leaving the room, and (6) working at something which did not "pan out." Although these and other causes provoke anger, certain times of the day are more anger-prone than others. Goodenough (1931), for instance, demonstrated that anger outbursts were most frequent around 11.30 A.M. and 5 P.M. Both hunger and fatigue were influential in determining incidence.

Closer inspection of the various anger-provoking situations in studies of young children reveals that they usually involve (1) physical disturbances such as opposition to daily routines, (2) failure of certain objects to work as they should, (3) physical discomforts, (4) interruption of interesting activities, and (5) thwarting of desire to do certain things. In older children, the physical factors continue to operate, but social factors such as interference by seniors or playmates predominate.

Adolescence. As the child matures, anger-provoking situations shift from being primarily physical to being primarily social. Hicks and Hayes (1938), for example, found that anger was aroused frequently in teenagers as a result of impositions by siblings or others, bossiness, unfair treatment, lies, sarcasm, and "things not going right." In another study, Meltzer (1933) sums up causes of anger among college students under the broad heading of thwarting. This may be broken down in several ways, however. Anger was more readily aroused by people than by things, although a sex difference appeared—women were more easily provoked by people and men by things. Thwarting of self-assertion aroused anger in 86 per cent of the cases as compared with 14 per cent for thwarting of activities. Thus, by late adolescence, prestige has become more important to these college students than physical activities. Typical responses of college women were, "That girl made slighting remarks about a friend of mine," or "The professor's daughter acted like she owned the place."

Adulthood and Old Age. Data are lacking on causes of anger in adulthood and senescence. Some clue is offered by a study of annoyances. Cason

(1930) made a comprehensive survey of the aversions and annoyances of persons aged 10 to 90 years. Average scores on the tests indicated that the number of annoyances increased up to middle age, leveled off, and then decreased from age 60 upward. The kinds of annoyances were far from constant: some tended to drop out while others replaced them. Among those which increased with age were such things as women smoking in public (this was in 1930!), reference to sex in a conversation, smelling liquor on anyone's breath, and walking on icy pavements. Decreasing in frequency were such items as gushing manners, grammatical errors, having to get up in the morning, and seeing people in dress inappropriate to the occasion. These data suggest that older people revert to a greater con-
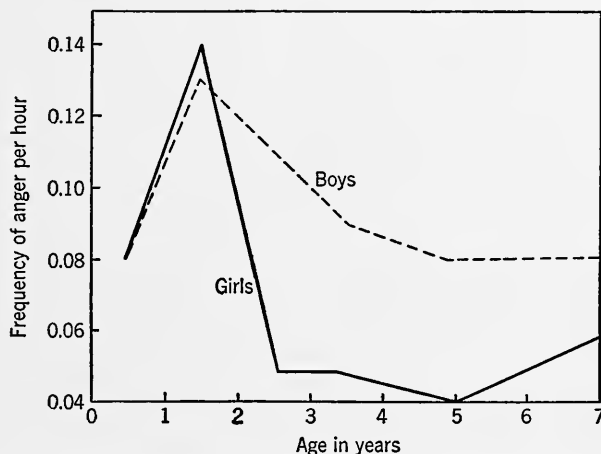
FIG. 91. The frequency of anger outbursts at various age levels. (*After Goodenough, F. L. Anger in young children. Minneapolis: University of Minnesota Press*, 1931.)

cern for physical welfare, while the younger adults have greater regard for customs and manners. The older generation, however, reflected the effect of older traditions, and it is difficult to judge whether age per se caused any change. Moreover, the items listed suggest disgust rather than anger. Thorndike (1935), who studied the reactions of adults aged 21 to 25 and over 30, reported no age differences in response to frustration or failure. Again, the findings are inconclusive, for the two groups compared differed little in age.

Age Differences in Anger Reactions. During early years, advancing age is marked by a trend away from physical toward verbal response or toward inhibiting expression entirely. Goodenough's (1931) illustration of the frequency of anger outbursts in children aged 1 month to 7 years is shown in Fig. 91. The peak of anger outbursts occurs around the end of the second year in both sexes. Although girls are slightly more prone to such eruptions, they also learn to inhibit overt expression sooner. The

most docile age for girls as well as for both sexes combined is around the fifth birthday. Subsequently, the frequency increases slightly.

Blatz *et al.* (1937) extend these data into adolescence, as shown in Fig. 92. Timidity decreases and fighting increases during the first year at school. Gradually, between ages 7 and 11, fighting loses ground as a method of expressing anger and by mid-adolescence has disappeared entirely. Sulkiness and impertinence replace it. As Goodenough states, there
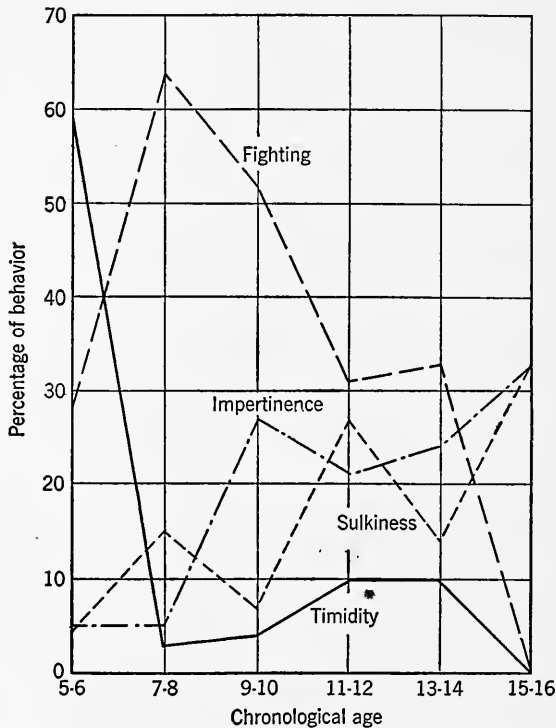
Fig. 92. Age changes in anger reactions. (*From Blatz, W. E., Chant, S. N. F., and Salter, M. D. Emotional episodes in the child of school age. Univ. Toronto Studies, Child Develpm. Series, 1937, No. 9.*)

are "more attempts to retaliate by means of indirect attacks designed to hurt the feelings rather than to injure the body of the offender." This substitution of other symptoms for direct expression continues through adolescence and adulthood. Richardson (1918), for example, found that in 600 instances of anger reported by 12 adults no blows were struck. In another investigation by Gates (1926), 40 instances were enumerated in which adults felt like making a physical attack upon another person, but only 3 actually did so.

Aftereffects of Anger. The child's temper tantrums or other anger responses are brief. According to Goodenough (1931), they last less than 5

min.—41 per cent, less than 1 min. There is no aftereffect; once they are over, a cheerful attitude prevails. However, as age increases and overt responses are replaced by sulking, stubbornness, and resentment, the duration of anger is extended, and unpleasant aftereffects appear. Meltzer (1933) states that 51 per cent of his college subjects reported definitely unpleasant reactions, especially after more violent outbursts. Of the 36 varieties of aftereffects listed, irritability was by far the most common. Occasionally, the subject experienced a sense of humor and turned the whole episode into a joke. Women were more prone to self-pity than men. In this age group, anger lasted anywhere from 5 min. to 2 days, with an average of 15 min.

No data are available for adulthood or old age. It might be anticipated that such variables as education level and socioeconomic status would affect responses. However, this is only a guess. More research is needed in this area.

Other Emotions

Jealousy and Envy. Both jealousy and envy emerge from the unpleasant roots in Bridges's schema (Fig. 87). Since both involve social situations, they cannot appear until such time as the child begins to recognize threats to his security and curbs to his wishes. Jealousy is directed against persons, envy against the possessions of other individuals.

Jealousy occurs more frequently during periods of life when affection centers on one or few individuals. It is common during early childhood, when the child wants the undivided attention of his parents and feels that siblings may threaten his position; it is rare during middle childhood, when he becomes a member of the gang and spreads his affection over larger numbers; it increases in frequency again in late adolescence, as he singles out one person for attention and is none too sure of his status in the eyes of the chosen candidate. At all ages, jealousy thrives on insecurity.

During early childhood, jealousy expresses itself in one of two ways: (1) physical attack on the person of whom the child is jealous or (2) regression to earlier modes of behavior that formerly succeeded in attracting attention. The reactions of adolescents and adults follow the verbal pattern exhibited in anger. This may consist of openly accosting the rival or of disparaging the rival before others but more often shows subtle approaches such as sarcasm, ridicule, or merely "forgetting" to invite a rival to a social function.

In young children, envy is also overtly expressed. If a child covets another's toys, he goes after them with teeth and fists. During the early school years, envy is at a minimum; more curiosity than envy is exhibited toward the possessions of others. As he grows older, however, the child

learns to attach more value to material things, and envy consequently increases. Responses to this unpleasant emotion often take on a negative, "sour-grapes" character. In adulthood, jealousy and envy usually center around wealth, prestige, and power.

Pleasant Emotions. Such emotions as joy, elation, and affection are usually grouped in the single category of pleasant emotions and are often referred to as positive reactions, since the subject makes no attempt to avoid them (as in the case of fear or anger) but rather tries to perpetuate them. According to Bridges's schema, delight differentiates from generalized excitement sometime around the end of the third month. Subsequently, delight undergoes further differentiation, so that by the end of the second year elation, affection, and joy have been included in the infant's repertory. Little is known about the pleasant emotions. Although they are important motivating factors in everyday behavior, they are difficult to study because they are not characterized by any pronounced physiological or overt reactions.

Causes of Joy, Elation, and Pleasure. Pleasant emotions may result from a variety of situations and conditions. One important factor is the general well-being of the individual—good health, nourishment, and the satisfaction of other bodily needs. Apart from this factor, there are other variables which show age differences.

Young children derive pleasure from pulling or tearing things apart, jabbering at or to other children, and generally engaging in noisy and boisterous play. With increasing age, the sources of joy and pleasure become more varied and more complex. In late childhood, for example, satisfaction and pleasure result from excelling in feats of skill and strength, since these promote social approval. Children also enjoy making things and taking them apart to see what makes them run. Adolescents derive pleasure from social activities such as dancing or group games and from literature, music, and other arts. They enjoy positions of social superiority—top marks, making the football team, dating the most popular boy or girl, and so on.

Affection. Affection is an emotional reaction directed toward persons, animals, or even inanimate objects such as toys. It is built up as a result of pleasant experiences with people or things. During early life, the child shows little discrimination among objects of his affection; often his liking for a pet or a toy is quite as pronounced as his affection for family members or playmates. As adolescence approaches, affection becomes directed primarily toward people and more rarely toward pets. In early adolescence, the youngster begins to select the objects of his affection a little more circumspectly. Usually the choice is narrowed down to include only family members, relatives, and his own sex. In later adolescence, affection centers first on several and later on one member of the opposite sex.

Age changes may also be noted in the expressions of affection. The responses of young children are quite spontaneous and uncontrolled; they appear in laughing, smiling, patting, fondling, or kissing. With increasing age, such overt demonstrations are inhibited, so that for a while adolescents may resort to the opposite extreme of abuse intermingled with such other expressions as smiling, physical relaxation, and attentiveness. Both adolescents and adults show affection through enjoying the presence of the other person or persons and by doing little favors.

CHAPTER 12

SOCIAL DEVELOPMENT

The next three chapters form a sequence concerned with social development from infancy to old age. Although the need for social relationships is basic to success and happiness, the social graces are unfortunately not inherited. At birth the infant is completely asocial. To the distress of most parents, he continues to lack even an appreciation of the desirability of becoming a social being for many years. The process of socialization is therefore long and often painful both to learner and to educator.

Of the various aspects of socialization, learning to get along with others is doubtless the most important. During preschool years, the child must learn to get along with members of his immediate family. As the environment broadens to include school, he must learn to cooperate with classmates and various adults who represent parental authority. Gradually he becomes aware that getting along with the many cultures, classes, colors, and creeds of our complex society is no mean problem. During adolescence, he is especially interested in members of the opposite sex and in gaining their favor. On entering the adult world, he is faced with the time-consuming tasks of finding and holding a job, winning a mate, rearing a family, and participating in the more or less demanding activities that hold a community together. To survive, he must learn the often paradoxical codes of the socioeconomic-political world. Finally, as old age encroaches on maturity, he looks out from his retirement to find his family scattered and the leisure activities for which he now has time curtailed by his own declining physical abilities. Once again he must learn how to live successfully within the narrowing sphere circumscribed by his own and economic limitations.

This thumbnail sketch gives a preview of the next three chapters. Social development has so many ramifications that not all of them can be dealt with here. Accordingly, this chapter will discuss age changes in group participation; Chapter 13, changing interests; and Chapter 14, changes in beliefs and attitudes. ·

To rid us of the popular notion that group life is peculiar to human beings, let us first briefly scan the social behavior of lower animals. We shall see that certain animals have social groups almost as complex as our

own, and we shall discover in them the rudiments of social behavior—friendship, cooperation, and dominance as opposed to submissiveness. This will serve to impress on us that many of our everyday activities are so basic that they are found even in the lower species.

SOCIAL BEHAVIOR IN ANIMALS

Investigations of the social behavior of animals are very extensive (see reviews by Crawford, 1939; Smith and Ross, 1952; Hebb and Thompson, 1954). Here we can mention only a few high lights, stressing the literature on vertebrates and the various evolutionary trends. First we shall examine the nature of social organization at different levels of the phylogenetic scale. Next we shall look at some specific types of social behavior such as dominance, cooperation, and friendship.

Appearance of Social Interaction. Social interaction is such a basic phenomenon that it may be observed in varying degrees among the lowest as well as the highest forms of life. In bacteria as well as in all grades of parasites, there are elementary examples of living things working together for mutual advantage (Buchanan, 1935). Invertebrates exhibit social interaction in varying degrees. The highly developed activities of certain social insects, for example, have prompted some investigators to assert that human and insect societies are so similar that it is difficult to detect any major differences between them (Wheeler, 1923).

Social Organization. It might be expected that the lower animals would have a very simple type of social organization and that social structure would become progressively more complex as the phyletic scale is ascended. Such an expectation is not altogether borne out, however. What might be considered complete social isolation occurs only in some of the lowest invertebrate forms, and even these occasionally congregate around a bit of food. On the other hand, certain of the arthropods come together only at mating time; others, such as the ants, have a highly developed society. Moreover, the lowly ant has a far more complex social structure than many vertebrates. Certain birds have a more complex social organization than some mammals, while others like the cuckoo come together only at mating time, and neither males nor females subsequently consort with either their own or the opposite sex or assume any responsibility for their own offspring.

The reason for this lack of parallel between social complexity and phylogenesis has often been debated. Tinklepaugh (1942) gives the following reasons:

Several factors are responsible for this general situation. Taxonomic classification is based upon relatively rigid and invariable structural differences. On the

other hand, social organization, while partially determined by structure, is largely the result of behavioral and physiological adaptation to highly variable environmental influences. This fact explains why different breeding habits may occur in animals of the same order, while animals of widely divergent orders may have the same breeding habits. It also explains why there is so little correlation between the complexity of social organization in a given form and the position of the given form in the phyletic scale [pp. 376–377].

Insect Societies. Most insects are socially solitary to the extent that they come together only at the time of mating. However, some of them, including ants, bees, and certain wasps and termites, have a highly developed social organization. It is these advanced societies that we shall examine.

Some idea of the complexity of such social structures may be gained from Wheeler's (1910) excellent description of ant colonies which may include anywhere from several dozen to several thousand ants. An important feature of colony life is the presence of castes, varying in number from one species to another but always performing a specific function. The queen is concerned with reproduction, the soldiers with protection, and the workers with various domestic chores such as caring for the young, bringing in food, excavating, and in general seeing that the colony functions smoothly. Since the domestic activities are so numerous, in some species there is a further differentiation of workers according to size— small, middle-sized, and large. Each subgroup performs certain prescribed tasks. For example, workers of a certain size cut out pieces of leaves and bring them into the colony where they pass them on to workers of another size which pack them into the solid balls on which fungus grows to provide food. This is an excellent illustration of cooperative activity.

From the above example, it can be seen that division of labor exists in insect as well as human societies. Among human beings, the division is only approximate and remains flexible; among insects, it is much more pronounced and much more rigid, revolving around the basic needs of reproduction, nutrition, and protection (Hebb and Thompson, 1954). Furthermore, in insects, this division of labor is related to certain structural differences among the castes. The queen, for instance, is often much larger than other members of the colony; many of the soldiers are equipped with large, powerful jaws, while the mouths of others contain a large secretory gland that excretes a sticky mass capable of disabling the enemy—both very useful protective devices. The workers, as has been pointed out, are of various sizes.

In addition to the caste system, the social structure of the social insects is characterized by presence of "slaves" and "guests." Although these are found primarily in ant colonies, they may also be observed among

wasps, bees, and termites. Slaves are generally captured on raids. Returning to the home colony, the victors put them to work at such domestic chores as caring for the young or bringing in food. The guests receive quite different treatment. They are usually sheltered in quarters next to the host's. Interestingly, they are usually smaller than the host, and their function seems to relate to size, for the small guest often climbs on the back of the host to lick its body; in return for this, the host occasionally (no doubt magnanimously) regurgitates some food for the guest. Non-ants such as plant lice are also treated as guests and are housed in special quarters, or "barns." They are often called "the dairy cattle of the ants," for when they are stroked by the ant they regurgitate honeydew.

Even this very brief description of ant society clearly illustrates why investigators have commented on the marked similarity of the social structures of insects and of human beings.

Social Facilitation. Social facilitation refers to increased activity resulting from the sight or sound of others engaged in similar tasks (Allport, 1924). It is common in everyday life. We eat and drink more in a crowd than when we are alone; industrial employees work faster in groups; more talking is done at a party than at home.

Social facilitation is so basic that it occurs even in the lowest vertebrates. It has been shown, for instance, that fishes in groups of two, four, and eight can learn an aquarium maze much more quickly than an individual fish. However, the phenomenon has been most clearly demonstrated in food consumption. Such vertebrates as fishes, birds, rats, cats, dogs, sheep, and monkeys eat more when in a group than when isolated. Individual differences are so great that for any one individual the increased consumption may vary from a few per cent to as high as 200 per cent over the amount eaten when alone. It has also been noted that, apart from quantity, several of the species mentioned eat and drink more frequently when in a group (see Smith and Ross, 1952).

Dominance-Submissiveness. Like social facilitation, dominance-submissiveness is so common that it is evident whenever two or more individuals are together and so basic that it appears even in very young children. Like social facilitation, it occurs in highly developed form in animals. The vertebrates, especially, often arrange themselves hierarchically, each playing a well-defined dominant or submissive role.

Perhaps dominance-submissiveness has been studied more extensively and more carefully than any other kind of social behavior of animals. Schjelderup-Ebbe (1935), however, contributed the first clear demonstration of this phenomenon in domestic chickens. He observed that one chicken would consistently peck another, which submitted to such domination. In turn, the second bird would peck a third, the third a fourth, and so on, forming a regular "pecking order." This social hierarchy remained

relatively stable. If a newcomer arrived, fighting would follow until the new chicken found its place in the hierarchy.

Since this pioneer work on chickens, other investigators have found similar stratification among fishes, reptiles, rats, cats, dogs, goats, sheep, cows, lions, monkeys, and chimpanzees (see Smith and Ross, 1952). The hierarchies are especially noticeable during critical food shortages, when competition is necessary for survival.

Whether an animal will be high or low in the hierarchy depends on a number of factors such as size, strength, sex, and age. These factors operate at all vertebrate levels, but social factors become more and more important in determining status as the phyletic scale is ascended. This is shown clearly in some observations on baboons (Maslow, 1936). Baboon A dominated animals B and C. On one occasion, however, when all three animals were together, B and C cooperated in giving A a severe beating. From that time on A became submissive to the others, even when only B or C was present. Hence, through cooperative action the animals were able to rise in the hierarchy.

Cooperation. So far, we have seen examples of cooperation in organisms as low as the social insects. Although insects show some very complex cooperative activities, these actions are of a reflex, nonpurposive nature (Hebb and Thompson, 1954). Literature on vertebrates provides many semianecdotal accounts of animals such as foxes, dogs, or monkeys joining together for some specific purpose such as attacking an enemy. Nevertheless, it has been maintained that although many such joint activities have all the earmarks of planned teamwork characteristic of human beings, they are psychologically only "accidents," since they are nothing more than a "simultaneity of individual actions set off by the same stimulus" (Nissen, 1951b). This is undoubtedly true of most of the lower animals; however, the rudiments of planned teamwork appear to be present in the higher primates, as will be seen.

Apart from human beings, perhaps the highest level of cooperation ever demonstrated experimentally is found in the chimpanzee (Crawford, 1937). This experiment has been summarized as follows:

In a laboratory experiment, Crawford first trained young chimpanzees individually to pull in a weighted box by means of an attached rope, in order to obtain the food reward on the box. Then the weight on the box was increased (so that one animal could not move it); next, two ropes were attached, the box was baited with two portions of reward, and two animals were put in the cage. At first each chimpanzee pulled without any reference to his partner's actions; only by chance did the two pull at the same time and so move the box. It was necessary for the experimenter to give a signal, which the partners had individually associated with initiating the pull, to get them to pull together. Once the temporal coordination of effort had been established in this way, the extraneous signal could be omitted.

One of the partners, A, usually watched the other one, B, and was ready to add her pull as soon as B started heaving on the rope. Sometimes it was arranged that B was satiated when the experiment began; A would then urge and direct B to pull. Eventually B would pull, although she had no desire for the food reward. Under these circumstances A often reaped the entire material benefits of the teamwork [from Nissen, 1951*b*, p. 444].

This description indicates that chimpanzees do show teamwork but of a very rudimentary kind involving little of the cooperation found in man. Furthermore, although teamwork was exhibited, it was achieved only in a situation in which the experimenter planned most of the activity.

Friendship. One kind of social behavior which shows considerable phylogenetic development is friendship between animals (Hebb and Thompson, 1954). In the lower organisms, attachments seem to be restricted to the reproductive period. Among birds and dogs, selective friendships frequently exist that last for a fairly long time. The most striking examples of enduring friendships appear further up the scale, among chimpanzees, however. Nissen (1951*b*) reports that some chimpanzees develop such strong friendships and dependence that when a long-time friend is taken away those left behind become restless, nervous, and highly irritable; lose their appetites; and often deliberately injure themselves. Providing substitute companions is of little avail.

SOCIAL DEVELOPMENT OF HUMAN BEINGS: SOCIALIZATION PROCESS

Socialization is the process of learning to act and to think like other members of one's society. The term applies equally well to animals and to human beings. Among human beings, however, the process becomes more complex, since it involves more thinking and often inhibiting behavior rather than acting directly. It covers a wide range, from learning to conform to the customs and mores of one's society through acquisition of language, gestures, symbols, or other communication media to learning the traditions and accepting the values of one's own culture.

The young child is "good" because he is punished for being "bad." He conforms because of external persuasion but does not realize the significance of either "goodness" or "badness" apart from reward and punishment. Later he is "good" because he wants to be "good." This means that he has accepted the values of his group and now assumes personal responsibility for his behavior. Thus true socialization involves a transference of authority from external to internal sources.

Agencies of Socialization. During preschool years, the home carries the entire responsibility for socializing the child. As contacts expand, the school, peer group, church and Sunday school, and various other organizations such as Boy Scouts, Girl Guides, and Cadets play increasingly im-

portant roles. Later, business and political institutions, service organizations, clubs, and lodges are influential. Newspapers, books and magazines, radio and television, movies, and theater play different roles at different ages but are always potent factors in socialization, especially in determining opinions, beliefs, and values.

PRESCHOOL PERIOD

During the early weeks of life, the infant gives no indication of true social behavior. Various writers have noted that during this period crying is often inhibited when the infant is picked up or caressed by the mother. It has been demonstrated, however, that crying ceases just as well when the child is caressed by a pillow or a warm hot-water bottle (Bühler, 1930). Thus, responses which have frequently been interpreted as social in nature are probably not social at all but due to changes in posture, temperature, or other such stimuli.

Appearance of Social Behavior. What appear to be true social responses appear quite early. In studying the social reactions of several hundred children between the ages of 1 month and 1 year, Bühler (1930) observed that well over 60 per cent of the infants aged 1 to 2 months cried when an attending adult left them, smiled in response to an adult's glance, and became restless when spoken to. Table 24 records the initial appearance of various social responses during the first year.

From the end of the first year, social development proceeds rapidly. This is due largely to the rapid advance in physical development. Once the child is able to assume a sitting posture, for example, he can watch others more easily. During the second year, walking enables him not only to

TABLE 24. AVERAGE AGE (MONTHS) WHEN AT LEAST 60 PER CENT OF INFANTS
SHOWED THE FOLLOWING SOCIAL RESPONSES*

Cries when attending adult leaves....................	1.5
Quieted by touching................................	3.5
Neglects play through meeting glance of adult..........	4.5
Smiles at another child..............................	4.5
Stretches hands toward adult........................	7.5
Cries when adult stops talking to him.................	7.5
Pulls on adult clothes...............................	8.5
Offers toy to another child...........................	8.5
Offers adult an object................................	9.5
Sets aside a toy and turns to another child.............	10.5

* Based on data of Bühler. Modified from Gurnee, H. *Elements of social psychology.* New York: Rinehart, 1936. P. 81.

watch but to follow, and his contacts expand quickly. He can move from room to room, follow his mother and other family members, watch their

activities, listen to their conversations, and generally explore his surroundings. With the acquisition of speech, he can voice objections and commands, ask questions, and thus begin to learn adult values.

Development of Social Responsiveness to Other Children. An excellent picture of the beginning of children's responsiveness to each other and of development during the first 2 years is given by Maudry and Nekula (1939). Pairs of children of approximately the same age were placed in a play pen with some toys, and their responses to each other were noted for 4-min. observation periods. The following trends were observed:

Six to eight months—about half of the social overtures to each other were ignored; friendly contacts were limited to looking, smiling and grasping for the partner; the partner was treated about the same way as the play materials; fighting consisted of impersonal and socially-blind attempts to secure play materials.

Nine to thirteen months—fighting was at its maximum with the child preferring "free" materials; conflicts became personal as the playmate received special consideration for the first time.

Fourteen to eighteen months—the child spontaneously shifted his attention from the play materials to his partner when his desire for playthings was satisfied; there was a decrease in conflicts over toys.

Nineteen to twenty-five months—the child integrated his social interests with his play material interests, capitalizing on the opportunity for social contact; the play was personal with much looking, smiling and grasping; play materials became an avenue through which children established social relations rather than a source of dispute and conflict [quoted in Thompson, 1952, pp. 450–451. Quoted by permission of publishers].

Here we see that children under 1 year of age show an incipient interest in other children. However, at this age they are able to deal socially with only one child at a time. If three infants are placed in a play pen, for example, interaction will occur between only two of them. It is not until the middle of the second year that a child will respond to two children simultaneously (data of Reininger, cited in Bühler, 1933).

Bridges's Study. We have considered social interaction in children until the end of the second year. In a very extensive investigation, Bridges (1931) takes us beyond this age. She noted a definite pattern of social development in nursery-school children and reports that

. . . between the ages of two and five years children in a nursery school progress from being socially indifferent infants, through the stages of self-assertiveness and interference with the liberties of others, to a stage in which they show consideration, sympathy and kindness for others. They then delight in group play and cooperate with one another for mutual enjoyment. They show real concern for the approval and disapproval of others, and express their own appreciation or disapproval in words rather than in action. Not all children reach this high degree of social attainment within the pre-school period, while, on the other

hand, some children under three show advanced social development. There are very noticeable individual differences. Moreover, children do not progress from stage to stage in uniform manner. They regress at times to earlier forms of behavior and develop new anti-social reactions. But, when all aspects of social behavior are considered together, most children show progress during the nursery-school period [Bridges, 1931, p. 85].

Appearance of Dominance-Submissiveness. One of the more conspicuous developmental features of the preschool period is the emergence of a hierarchy in which some children dominate while others play submissive roles—much like the pecking order of chickens. The development of such a hierarchy is well illustrated in a study by Jack (1934), in which preschool children were observed in a competitive situation. The children were brought in pairs to a room containing a sand playbox and other toys. Their responses to each other were then observed through a one-way screen. A child was given a dominance score each time he did one of the following: (1) verbally or physically attempted to get the play materials, (2) succeeded in getting the toys, (3) was able to get another child to carry out some action, (4) criticized or reproved his companion, and (5) performed an action which his companion imitated. Each child was paired with every other child. Dominance scores ranged from very high to very low, although most preschool children scored about midway in the scale. Training the submissive children in the use of materials significantly increased their dominance scores. Other investigators have supported this finding that submissive children can become quite socially assertive through appropriate encouragement and guidance (Page, 1936).

Social Growth as Reflected in Play. Children's play activities tell much about the status of their social development. One of the best studies on the nature of play in preschool children, aged 2 to 5, was reported by Parten (1932, 1933). The children were taken out into a play yard and allowed to play either alone or with others. Twenty 1-min. samplings of behavior were recorded for various occasions. The following types of activities were noted:

1. *Unoccupied behavior,* in which the child watches anything of momentary interest and plays with his body if there is nothing else to do.
2. *Onlooker behavior,* in which the child watches other children at play. The child often talks to the children at play or gives suggestions but he himself does not overtly enter into the play.
3. *Solitary independent play,* in which the child plays alone and independently with toys different from those of other children and without reference to what they are doing.
4. *Parallel activity,* in which the child plays independently but with toys like those used by the other children. He plays beside other children rather than with them. Does not imitate their actions.

5. *Associative play*, in which the child plays with others. In this play, all other children in the group engage in similar if not identical activity. "Turns" are taken or material is interchanged.

6. *Cooperative or organization supplementary play*, in which the child plays in a group organized to make some material product or to play some game. The group is controlled by one or two members who direct the activity of the others.

The proportion of each of these types of play appearing at different ages is shown in Fig. 93. The 2-year-old is rarely either unoccupied, an onlooker, or cooperative. He engages in both solitary and associative group play, but by far the greatest proportion of time is spent in parallel play. The child likes to sit among other children and play with his doll, Teddy bear, blocks, or beads while others play with theirs. Much of the play activity
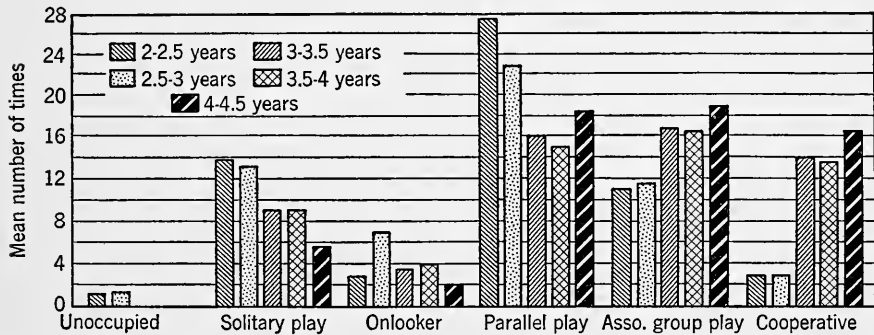
FIG. 93. Types of play engaged in by preschool children. (*From Parten, M. B. Social participation among preschool children. J. abnorm. soc. Psychol.*, 1932, **27**, 260. *By permission of the American Psychological Association.*)

consists of patting, pounding, or feeling his toys, since he has little motor dexterity as yet. He does not ask for help, nor does he imitate the activities of others unless they happen to be in direct line of vision. Any contact is apt to result in snatching, pushing, and screaming; there is no social give-and-take. Associative and cooperative play are both infrequent prior to the third year, but from this age on they increase markedly while other types decline. This is due to the fact that language is necessary for cooperative undertakings. After the age of 4, such cooperative ventures as playing store, house, or school become popular.

Play and Attention Span. Although preschool children spend much time in play, they shift from one activity to another very often. This applies to story listening as well as play. The attention span at this time is short. Van Alstyne (1932) collected the following data on the length of attention span at various ages: at 2 years, 6.9 min.; at 3, 8.9 min.; at 4, 11.4 min., and at 5, 12.6 min. The duration of an activity may be longer or shorter, however, depending on the activity itself, but the range is never

great. Attention span continues to increase throughout childhood and adolescence.

Stages in Social Responsiveness to Adults. The preschool period may be roughly divided into three stages with respect to social relations with adults (Bridges, 1931): (1) There is first a dependent stage, during which the child relies on adult assistance and accepts it passively. (2) This is followed by a period of resistance, which reaches a peak between the ages of 2½ and 3 years—often called the "negative phase." During this time the child rebels against adult influence and help. "No, let me do it!" is the characteristic slogan. (3) Finally, there appears a period of cooperativeness and friendliness, which lasts through the fourth and fifth years, to the great relief of most parents.

The child's early conversation with adults consists of refusals and demands. As vocabulary increases and as the negative phase wanes, he begins to relate experiences and to ask questions. During the preschool years he usually looks upon adults as all-wise, all-powerful, and quite infallible.

Summary. Social development proceeds slowly during the premotor and prelinguistic ages. This slow start is followed by rapid progress throughout the preschool years. By the time the child starts school, he has mastered the basic elements of language, has learned to conform to many of the everyday demands of his society, knows how to get along reasonably well with parents and playmates, and is beginning to understand some elementary values.

MIDDLE CHILDHOOD

"Middle childhood" is the term commonly used to designate the interval between starting school and puberty (see Gesell and Ilg, 1946, for fuller treatment of the early school years). Since girls reach puberty earlier than boys and since individual differences are great, the age limits are necessarily flexible.

The average child is eager to begin school. He has heard a great deal about it and looks forward to new playmates and new experiences; he considers it a sign of growing up. If he has passed his "preparatory courses" by learning to get along with family members and playmates and by sharing in cooperative play, he will have little difficulty in adjusting to the new school situation.

During early school years, friendships are easily made and easily broken. Children continue to cling closely to home ties. They definitely break away from solitary and parallel play situations, however, and favor cooperative effort in both work and play. Goodenough (1945) aptly describes the changing social relationships. She states that, although we find the beginnings of socialized play during preschool life, it is egocentric in

nature: "I want someone to play *with me*." During the early school years, this egocentricity wanes, and the child substitutes "I want to go and play *with the other children*." This change is one of the first signs of identification with the larger group and of a dawning recognition that "we" carries more weight than "I."

As the child starts school, he is faced for the first time with the conflicting values of adult society. Such conflicts contribute to a disregard of adult standards during middle childhood and to the formation of childhood gangs, absorbed in their own activities and guided by their own peculiar values. This will become clearer in later sections.

Middle childhood, especially the later part of middle childhood, is characterized by three distinct trends: (1) rejection of adult standards, largely accepted until this time; (2) sex differentiation, expressed superficially in antagonism toward the opposite sex; and (3) formation of age-sex social groups, called "gangs" (Blair and Burton, 1951). Let us consider these trends one by one.

Rejection of Adult Standards. We have already noted a negativistic phase as early as the third year. This early negativism is short-lived, however, and the young child soon comes to regard his parents as all-wise, all-powerful, and infallible. This view persists through the first school years but with less and less conviction. The child may rebel against adult restrictions that interfere with his wishes or activities, but at first he does not challenge them. Through exchanging views with schoolmates, visiting their homes, and otherwise broadening his contacts, however, he soon learns that the codes of his own parents may differ from those of other parents and of the school. As observations and understanding increase, he realizes that rules are man-made and may therefore be challenged and that even his own parents are fallible. This awareness leads directly to a second "negative phase," characterized by lack of punctuality, discourtesy, inattentiveness, carelessness, untidiness, subtle rebellion, and disobedience (Piaget, 1932)—an abrupt reversal of earlier progress and a backward step as far as social development is concerned.

This period of rejection of adult standards has frequently been associated with puberty or early adolescence. Probably this is due to gaps in the existing data, since comparisons of early childhood with adolescence have clearly pointed to changed attitudes, while lack of evidence for middle childhood has prevented any accurate placement of the rebellious phase. Blair and Burton (1951), however, who reviewed the meager literature on middle childhood, point out that the second negativistic phase probably begins long before puberty. Several studies support this view. For example, Blatz and Bott (1927), who studied 1,437 school children, found that the peak of unruliness occurred around the age of 9 in boys and around 10 or 11 in girls. They also noted that such behavior as

disorder, lack of cleanliness, disobedience, and deceit was high during these years but had practically disappeared by the age of 13 or 14. Jones *et al.* (1939) likewise state that teachers of 10- to 12-year-old children report more behavior problems than teachers of older children. Cumulative evidence thus indicates that the second negativistic phase falls well within middle childhood rather than in adolescence (see Blair and Burton, 1951, for further discussion).

Sex Differentiation. Young children play with their own or the opposite sex without apparent preference. Soon after starting school, however, boys and girls begin to show considerable antagonism toward each other. This developmental picture is well illustrated in a longitudinal study by Campbell (1939), who observed the same subjects in free-play situations at various ages. She noted that up to the age of 7, children ignored sex in choosing companions and play groups. By the eighth year preferences began to appear, and by the ages of 10 and 11 complete segregation of sexes was usual. Any contact between boys and girls resulted in teasing, quarreling, and ridiculing each other. Segregation passed through several stages; it began with aloofness, which was followed by contempt and finally by hostility. This last stage merged into shy withdrawal, which seemed to mark the termination of the sequence and the beginning of adolescence.

Certain differences characterize the attitudes of the two sexes. Although members of either sex regard themselves as superior, girls at all these ages have a higher regard for boys than boys have for girls. By the age of 14, girls have reached a stage at which they think almost as well of boys as they do of their own sex. Boys of this age are still hostile (Smith, 1939).

Not only do the sexes like to play separately during middle childhood, but they also prefer doing schoolwork and home chores with members of their own group. This period of sex differentiation, when the two groups set up different standards of conduct, is of great significance to social development, for during this interval youngsters learn their future roles as members of their own sex.

Formation of Gangs. Since children reject adult standards and also disclaim interest in the opposite sex, it is not surprising that they should turn to some kind of elementary social organization. To the children themselves, such social groups are known as "gangs." The period of the gang extends from the seventh to around the twelfth year.

The gang is a relatively small social unit, usually comprised of five but seldom more than eight members of the same sex and age. It has only two prerequisites for membership: living in the immediate vicinity and being a "good sport" in the child's sense of the word. Gangs are usually formed spontaneously. Little consideration is given to such factors as common interests, personal appearance, socioeconomic status, or ability to get along

with others. Neither ethnic origin nor color is a barrier unless the children happen to come from homes where such differences are emphasized.

Since gangs are loosely organized, they have no leaders during the early stages, but great respect adheres to such characteristics as physical strength, skill, and ingenuity in thinking of new and more daring activities. As time passes, however, leadership develops. The aims of the gang are selfish. They usually concern recreational activities, but they may have other objects depending on membership. Thrasher (1927), for example, traced the source of many cases of juvenile delinquency directly to the gang. The gravitation of all children toward gangs is not motivated wholly by a desire for activity; prestige is also a factor. This is evidenced by such things as passwords, secret codes, initiation ceremonies, in- and out-group attitudes, and the name used to designate a gang. Gangs are important sources for ideas of right and wrong and also serve as a guide to dress, manners, and other forms of behavior. The strong bond holding gang members together is the resistance to adult authority.

Sex Differences. Goodenough (1945) discusses the difference between boys' and girls' gangs. Girls' groups are often called cliques instead of gangs. They are less well organized, less conspicuous, and less frequently studied, since they are less dramatic. Girls' cliques are believed to have little purpose apart from being a defensive measure against boys' gangs. Since girls mature earlier, they are less hostile to adult authority at the later ages.

Play Activities. It is not strange that children should fail to consider community of interests as a prerequisite for admission to the gang, for at this stage they are interested in almost everything. The peak of variety in play activities is found near the beginning of the gang age, around the ninth year (Lehman and Witty, 1927a). Probably the diversity is due to the child's increasing motor facilities and endurance coupled with limited appreciation of organized activities. Children switch from game to game and from one activity to another without intermission. From the age of 9, however, both interests and participation tend to become channeled into fewer and deeper grooves (see also Chapter 13).

The trend toward fewer activities is well illustrated by Fig. 94, which shows the median number of play activities for a large number of children from the ninth year to adulthood. It is noteworthy that, despite the general narrowing, the children who participated in the most activities during childhood tend to do so in adulthood; children who engaged in few activities also carry this pattern into later years.

During the early school years play continues to revolve around gross motor activities: skating, swimming, diving, playing follow-the-leader over fences and other obstacles, skipping rope, flying kites, and so on. With advancing age the interest in rules increases, and hence organized

play tending toward sports begins to appear. Middle childhood differs from the preschool period in that activity is no longer an end in itself but a means toward an end. Thus, the young child runs for the sake of running, but the 10-year-old runs to win a race or to "steal a base" in a game.
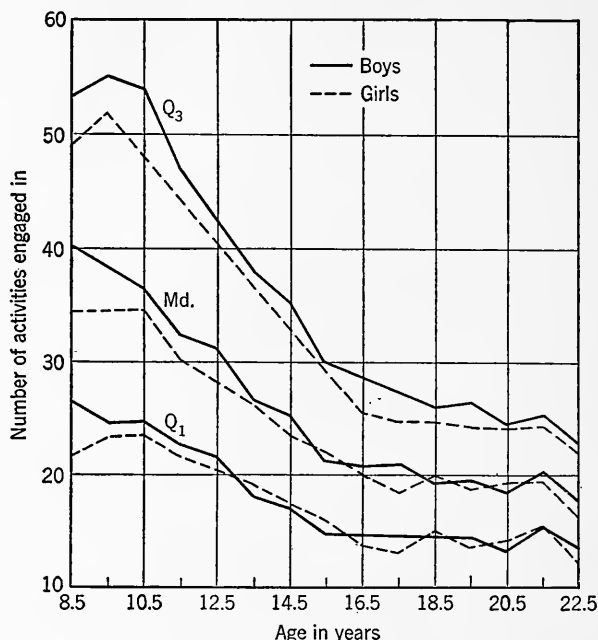
Fig. 94. The number of different play activities engaged in by boys and girls of various ages. (*Modified from Lehman, H. C., and Witty, P. A. Psychology of play activities. New York: A. S. Barnes*, 1927.)

Activities become less spontaneous and increasingly structured and formal.

ADOLESCENCE

Adolescence is the transition period between puberty and adulthood. It is an interval of social and emotional adjustment to changing physique, a "practice period" for learning to play an adult's instead of a child's role in society. The child made considerable progress toward socialization; he learned to get along with others of his own age and sex in various situations both in and out of school and with parents and teachers. However, he had little experience with adults outside of school and home and withdrew entirely from the opposite sex. The adolescent must carry on where the child left off, and so it becomes his peculiar problem to learn to adjust to the opposite sex in preparation for establishing a home and to adjust to

adults in preparation for earning a living and playing a role in his own community (for fuller treatment of the adolescent period see Hurlock, 1949; Horrocks, 1951; Garrison, 1951).

Adolescent Home Relationships. Although the period of resistance to adult standards begins in middle childhood, it has not spent itself by the time of puberty, and differences of opinion between adolescents and parents continue to complicate home life. These differences often concern minor events. The emphasis on the negative aspects of parent-child relationships has been so great in recent years, however, that more trouble is anticipated than actually occurs. If the child has been well adjusted during earlier years, the adolescent continues to be so; if the child has been coping with problems which he cannot solve, the earlier discontent often erupts during the adolescent period.

Causes of Friction. Numerous investigators have attempted to diagnose the sources of friction in the home. Block (1937), for example, used a questionnaire method for this purpose, distributing forms to 528 high-school students. According to his data, most home conflicts arose from differences in thinking regarding (1) personal appearance, habits, and manners; (2) vocational, social, recreational, and educational choices; (3) the value of certain activities, attitudes, etc., as means of achieving a goal; and (4) the philosophy of certain recreational and physical activities. Many of the controversies arose not out of the situation per se but out of the mother's way of handling it. Girls had most conflicts during the seventh grade (around ages 13 and 14), boys a year later. Beyond these ages, conflicts diminished for both sexes.

On the positive side, Stott (1940) reports that many adolescents accept the home situation—or at least refrain from criticizing it before outsiders. A group of 1,878 teen-agers were studied by a questionnaire technique essentially similar to the one used by Block on the smaller sample already cited. The data obtained indicated that only 35.9 per cent criticized anything in their mothers' behavior and only 36.2 criticized their fathers. Thus, roughly two-thirds of these adolescents appeared to have no serious home difficulties. Questionnaire techniques not supplemented by other devices are open to criticism, however. Many youngsters may have problems and yet have sufficient loyalty to the family group (or sufficient reticence) to refrain from discussing their problems. For a percentage of adolescents, at least, this is probably true even when questionnaires remain unsigned.

The home problem was approached from another angle by Arlitt (1942), who reversed the process by asking parents about their children's behavior. He found that disobedience, untidiness, impertinence, and talking back led the list of grievances. This seems to point to the orthodox traditions of the older generations which demand implicit obedience as long

as the child remains under the parental roof. Other investigators support Arlitt's findings (see also Chapter 14).

Adolescents' Social Groups. During adolescence, several kinds of social units are formed. In these social groups the teen-ager acquires and practices many of his social skills, for example, dancing and conversation. Here he learns to get along with members of the opposite sex and also learns many of the values and attitudes of his society. Only the most clearly recognizable groups will be discussed here.

The Crowd. The largest social unit at this time is the crowd (Hurlock, 1949). The crowd differs from the preadolescent gang in almost every comparable respect: (1) Childhood gangs are formed spontaneously on a basis of propinquity; the adolescent crowd is carefully selected on a basis of common interests, socioeconomic status, congeniality of members, personal attractiveness, etc., and its members often live a considerable distance apart. (2) The gang is made up entirely of one sex; the crowd draws from both sexes. (3) The gang numbers five to eight members; the size of the crowd is variable but usually large. (4) The gang engages in physical activities involving excitement and adventure; the crowd is social in character. (5) The gang is loosely organized; the crowd is held together by common interests. (6) The gang is selfishly motivated and often gets into trouble; the crowd is usually harmless, although parents may frequently disapprove of it.

In spite of their informality, adolescent crowds serve a number of purposes apart from recreation: (1) they provide a feeling of security at a time when the individual cares little for adult company and less for his juniors; (2) they provide experience in getting along with others and in evaluating people; (3) they afford opportunities for practicing social skills; and (4) they provide a basis for tolerance, understanding, loyalty, and courtship. On the negative side, (1) they tend to encourage clannishness and often downright snobbery, making adjustments of nonmembers more difficult, and (2) they are detrimental to studies and other duties. The adolescent crowd with its own fads and fashions, jargon, and interests exerts tremendous influence on both members and nonmembers; it dramatizes concretely the adolescent fear of being different.

Adolescent crowds have been classified according to purpose by Dimock (1937). They may be special-interest groups, promoting a sport or a dramatic or other activity. This type is well exemplified by the teen-agers who congregate in one bleacher section to cheer for the home team and only incidentally to see the game. Secondly, they may be clubs which include several activities. Thirdly, they may be purpose groups of an idealistic nature, such as the Hi-Y clubs. Lastly, they may be merely neighborhood groups based largely on propinquity.

The Clique. Crowds usually begin as aggregations of smaller groups, called cliques—not to be confused with the female "gang" of middle childhood. The clique is a small social group numbering anywhere from two to a dozen intimate friends of both sexes whose attraction depends on common interests, likes and dislikes, and social standing in the community. Usually the cliques are held together by strong emotional ties. Hollingshead (1949) divides cliques into three types: school, recreational, and institutional. The school clique may be seen around the campus between or after classes, engaged in any activity of interest at the moment. The recreational clique may consist of the same members or it may include some and exclude others (because of distance or other reason) and make up the necessary complement for a game of tennis or other recreation by drawing on other cliques of comparable status. Institutional cliques draw their members from larger groups. Good examples are junior leagues or institutes which are formal and involve leadership.

The Gang. The adolescent gang is not to be confused with the boyhood gangs of middle childhood. Adolescent gangs are more highly organized than either crowds or cliques. They invariably result from tensions or conflicts and are often involved in serious difficulties with police or other authorities. Because of this, the adolescent gang has greater continuity, for loyalty is ensured by common risks and common dangers. The conflicts may derive from religious, racial, or ethnic pressures, or they may grow out of lack of understanding in the home. Such gangs are therefore atypical rather than typical adolescent societies.

Gangs are found chiefly in urban areas lacking in recreational facilities. Because of their location and because of maladjustment to family or society, they often lead to aggression and delinquency. Much literature is available concerning these groups, especially in metropolitan areas such as New York and Chicago.

Importance of Adolescent Peer Culture. To the student of human development, the formation and structure of adolescent groups are important because of the great impact of such groups on behavior. Members of a clique, crowd, or gang tend to rate peer-group values above those of even the family, at this time. Teen-agers who are excluded from membership bitterly resent the exclusion. The values and attitudes formed in this environment far outlast membership in the group. Although many of these values and attitudes are beneficial, not all are in the best interests of later adjustment.

Leisure-time Activities. The leisure-time activities of adolescents vary with changing times and facilities, depending on sources of recreation, money, distance, etc. Table 25 lists the percentage of adolescents who participate in various recreational activities. Most popular are dancing

and dating, reading, individual sports, loafing, and movies. At this age, listening to the radio and engaging in quiet games are near the bottom of the list.

Perhaps the outstanding feature of Table 25 is the marked relationship between preferred activities and education level. The young people who left school with little or no education prefer loafing, dancing and dating, and individual sports, in that order. At the other end of the educational continuum are the college graduates with 4 or more years of school beyond high-school graduation who prefer reading to all other forms of recreation. At this level, reading is followed by individual sports and hobbies, but neither the second not the third were named half so frequently as reading. Loafing decreases from 21.7 to 4.3 per cent as education level increases, while reading rises from 11.5 to 42.9 per cent. The steady progressions between these two extremes indicate that education is effective in eliminating loafing and encouraging reading. While quality of reading is not indicated, it can be noted from other sources that quality improves with increasing education (see Chapter 13).

Table 25 also shows some decline in active participation in physical activities from the sixth grade through college. According to these data, the less well educated are more interested in team games and less active in individual sports than the better educated. The differences, however, are not great.

TABLE 25. PRINCIPAL LEISURE-TIME ACTIVITIES OF OUT-OF-SCHOOL YOUTH ACCORDING TO THE SCHOOL GRADES THEY COMPLETED*

Activity	Percentage of youth in each group					
	6th grade or less	7th or 8th	9th, 10th, 11th	11th or 12th graduate	1, 2, or 3 years beyond high school graduate	4 or more years beyond high school
	$N = 1,483$	$N = 2,762$	$N = 2,569$	$N = 2,885$	$N = 770$	$N = 396$
Reading..................	11.5	17.9	23.3	32.2	42.6	42.9
Individual sports............	12.4	13.5	15.9	15.6	15.2	18.4
Dancing, dating.............	12.6	10.9	15.5	14.0	10.4	8.3
Movies....................	9.4	12.8	13.4	10.2	8.2	7.6
Loafing...................	21.7	15.8	7.5	5.9	3.9	4.3
Hobbies...................	8.7	10.1	8.4	10.4	10.7	9.9
Team games...............	10.1	8.2	8.7	5.4	4.0	3.5
Listening to radio...........	2.8	2.4	2.3	1.8	0.9	1.0
Quiet games...............	2.2	1.8	1.0	0.7	0.9	1.8
Other activities.............	8.6	6.5	4.0	3.8	3.2	2.3

* Adapted from Bell, H. M. *Youth tell their story.* Washington, D.C.: American Council on Education, 1938.

Development of Heterosexual Interests. One of the more conspicuous developmental features of the adolescent period is the emergence of interest in the opposite sex. During middle childhood, whatever heterosexual interests are present seem to be directed into competitive efforts against the opposite sex. It is difficult to say when the heterosexual interests begin to develop. In a questionnaire study of over 1,000 adolescent boys, Hughes (1926) noted the first signs as early as 12.5 years. Interest in the opposite sex passes through several quite well-defined stages. Of these, the three clearest are (1) a crush hero-worship phase, (2) a boy-crazy or girl-crazy phase, and (3) a phase of romantic interest. These will be examined in the order named.

Crush Hero-worship Phase. As the adolescent moves from the stage of strong dislike for the opposite sex, evidenced in late middle childhood, to the period of romantic interest, in the later teens, he frequently passes through a phase of strong attachment for an older person of either the same or the opposite sex. When such attachment is focused on an individual of the same sex, it is called a "crush"; when on a member of the opposite sex, "hero worship."

The object of a crush is someone whom the adolescent admires. It may be an older schoolmate who has distinguished himself in one way or another, a teacher, or a glamorous movie or radio star. The basis of the attraction is usually some quality or ability possessed by the object but lacking in the adolescent. Affection may be expressed through gifts, notes, imitation of mannerisms, etc., but not through physical contact. Crushes are most frequent around puberty and early adolescence, are more common among girls than among boys, and usually last about 6 months (Hurlock and Klein, 1934).

Hero worship is more common than the crush. The usual objects are movie and radio stars or public figures, but they may be persons from the immediate environment. Hero worship does not necessarily involve knowing the object; the recipient may often be completely unaware of it. Characteristic behavior consists of "adoring from a distance," attempting to dress and act like the hero or in a way the hero might approve, and professing sophistication. This phase is often called "calf love."

Boy Crazes and Girl Crazes. Sometime during the later high-school years, the adolescent transfers his affection from older individuals to members of his own age group but of the opposite sex. An interesting feature of this transition is that for awhile admiration includes boys or girls in general rather than any specific boy or girl. In view of girls' earlier maturation, they enter this phase a year or two earlier than boys, usually around the age of 15.

This period is often called the "puppy-love" stage, obviously because of the continuous teasing, wisecracking, playful jostling, and other atten-

tion-getting devices. Much time is devoted to personal appearance designed to secure the attention and approval of the opposite sex. In contrast to earlier shyness, behavior at this time is quite aggressive.

Phase of Romantic Love. Normally, this phase commences in late adolescence. It is a more stable, mature, and intense affection than puppy love. The person involved is so preoccupied with one individual that he tends to ignore all other members of the sex and also the group activities in which he was formerly interested. Preferred recreations are restricted to the couple concerned or may perhaps extend to a foursome. This is the period
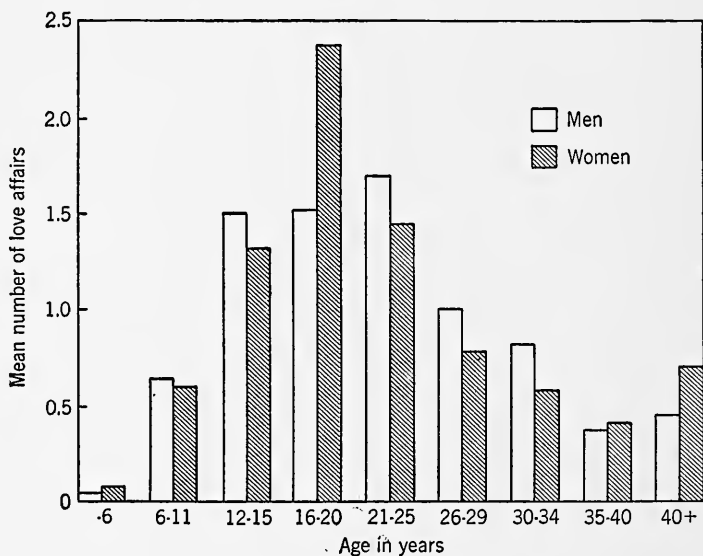
Fig. 95. Average number of love affairs between early childhood and adulthood. (*After Hamilton, G. V., and MacGowan, K.   What is wrong with marriage? New York: Boni, 1929. P. 257.*)

of intensive rather than extensive dating. However, although the attachments may be strong, most adolescents have several of them before they eventually marry.

Figure 95 shows the incidence of such love affairs at various ages from childhood through adolescence. As may be seen, the incidence is highest for girls between 16 and 20 and for males between 21 and 25 years—a finding which again points to the earlier maturation of girls. Note the slight increase of romantic love affairs after the age of 40 years in women.

Expressions of Romantic Interests. As the individual develops physically, and as heterosexual interests reach the phase of romantic love, it might be expected that the desire for physical contacts also increases. Teen-agers of various generations have coined the terms "necking" and "petting" to designate the more or less acceptable forms of physical con-

tact. These include kissing, fondling, and stimulation of erotic zones. Necking and petting begin sometime in middle or later adolescence, and in some cases earlier.

Sexual Intercourse. While necking and petting are tolerated by some parents, there is almost wholesale opposition to sexual intercourse. Nevertheless, such data as we have indicate that it is more common today among teen-agers than a few decades ago. Doubtless the most extensive survey in this field is that of Kinsey *et al.* (1948), who report that while sexual intercourse is common in adolescence, frequency is highly related to
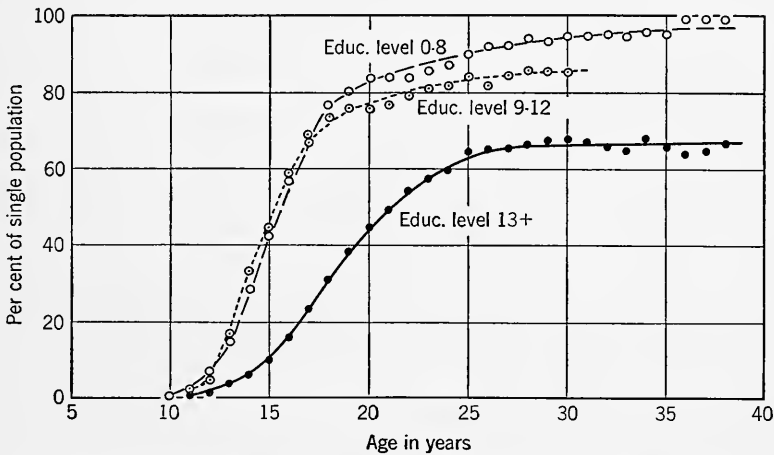
FIG. 96. Age changes in premarital intercourse: accumulative incidence in three education levels. Data are based on unmarried males. (*From Kinsey, A. C., Pomeroy, W. B., and Martin, C. E. Sexual behavior in the human male. Philadelphia: Saunders, 1948. P. 551. By permission of the publishers.*)

education level and to socioeconomic status. Kinsey somewhat drolly summarized his findings thus:

So nearly universal is pre-marital intercourse among grade school groups that in two or three lower level communities in which we have worked we have been unable to find a solitary male who has not had sexual relations by the time he is 16 or 17 years of age. In such a community, the occasional boy who has not had intercourse by that age is either physically incapacitated, mentally deficient, homosexual or ear-marked for moving out of his community and going to college [p. 381].

Figure 96, taken from Kinsey *et al.* (1948), shows the percentages of American males of three education levels who have had premarital intercourse. It will be noted that those with little education who leave school at elementary level begin their sex experiences earlier; 40 per cent have had

intercourse by the age of 15, and another 40 per cent during the next 5-year span. The difference between the elementary- and high-school groups is not great, although the curves diverge slightly around the age of 17 or 18 years. The college group differs markedly, however. College men begin their sex experiences considerably later, and less than half have had intercourse when they graduate at the age of 22 or 23. According to Kinsey, these education-level trends correlate highly with socioeconomic status.

Frequencies of premarital intercourse parallel social and education levels even more closely than does incidence. During the period from 16 to 20 years, the elementary-school group has seven times the incidence of the college men, and nearly half of the males who do have intercourse during college years began the practice while they were still at home. Evidently mothers can stop worrying about sending their offspring away from home to college. The risk of keeping them in the home town is far greater.

How much of this heterosexual sex activity involves adolescent girls? In one study it was found that the "partners" of the younger adolescent boys were usually neighboring friends, relatives, or girls met on visits— about 80 per cent of them within 1 year of the boy's own age. The partners of the older adolescent boys were friends, pickups, prostitutes, fianceés, and older women (Ramsey, 1943).

Incidence of Marriage in Adolescence. The climax of heterosexual interests is marriage. Although marriage is not generally associated with adolescence, census data indicate that teen-age marriages are more prevalent than is commonly thought. Table 26 records the percentages of the American white population, aged 14 to 19, who marry in their teens. By the age of 19, roughly one-sixth of all American young people are married, the incidence being considerably higher for girls and lower for boys. There are wide regional differences, however. For example, about 14 per cent of all 19-year-old girls living in the Middle Western states are married as compared with 38 per cent in the South.

Preparation for Work. As the individual approaches maturity, he becomes more and more concerned with selecting a vocation. Vocational interests do not emerge full blown in adolescence, however; their roots reach back into childhood. Children usually begin to think of vocations in terms of work that is high in excitement but low in prestige; for example, they want to be cowboys, soldiers, railway conductors, and aviators. Becoming an explorer is a popular choice among boys, while actresses, models, and nurses rank high in favor among young girls.

The fluctuating vocational interests from childhool to adulthood are well illustrated in Fig. 97, based on an analysis of the vocational histories of a group of teachers. Between the ages of 6 and 8 years, the male teachers aspired to become railway engineers, at 14 they wanted to be football players, and at 16 either doctors or engineers. The female teachers planned

on becoming actresses, musicians, or nurses at 12 to 14 years; from 13 to 18 they showed a preference for office work and later for library work. They all actually became teachers. Although these data were obtained from a narrow sample, they are typical of the changing interests of most youngsters.
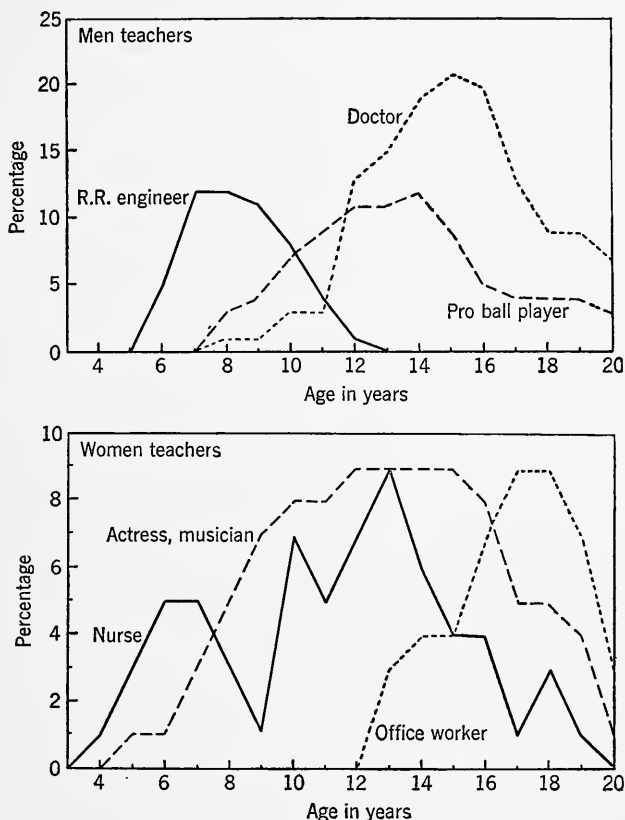
FIG. 97. Fluctuations in specific vocational interests from childhood to adulthood. (*From Norton, J. L., and Kuhlen, R. G. The development of vocational preferences. In Kuhlen, R. G., and Thompson, G. G. Psychological studies of human development. New York: Appleton-Century-Crofts, 1952. P. 447. By permission of the publishers.*)

During the high-school years, the teen-ager becomes more capable of appraising his own abilities and limitations and learns more about supply and demand and the prerequisites for various jobs. As a result, his vocational aspirations gradually become more practical. Frequently, however, he obtains too much information too quickly and may be unable to decide, vacillating until he is pushed into something by parents or other adults.

Vocational Interests in Relation to Job Opportunities. The vocational preferences of adolescents are often unrealistic in terms of opportunities.

In one investigation it was found that 70 per cent of a group of adolescent boys wished to enter a vocation in which only 35 per cent of the population was employed. On the other hand, only 1 per cent chose laboring jobs in which 30 per cent of the population was engaged (Kroger and Louttit, 1935). Another study reports that around one-third of the subjects

TABLE 26. PERCENTAGE OF WHITE TEEN-AGERS WHO ARE MARRIED*
(Based on 1940 census data)

Area	Age					
	14	15	16	17	18	19
Total United States:						
Males...................	0.1	0.1	0.3	0.7	2.1	5.3
Females.................	0.3	1.1	3.8	8.8	17.3	26.4
Middle Western States:						
Males...................	0.1	0.1	0.2	0.3	0.8	2.2
Females.................	0.1	0.2	0.9	2.7	7.2	13.8
The South:						
Males...................	0.1	0.2	0.4	1.2	3.7	9.1
Females.................	0.6	2.4	7.3	15.7	27.1	37.9

* From Kuhlen, R. G. *The psychology of adolescent development.* New York: Harper, 1952a. P. 312. By permission of the publishers.

selected three professions which according to census data for 1930 account for less than 7 per cent of all employment (Rainey, 1937).

Similar discrepancies occur between interests and ability essential to success in the preferred vocations. Many adolescents appear to be influenced by the tradition that they should choose "better" occupations than their parents (Bell, 1938).

Factors Influencing Choice. What factors determine the adolescent's choice of a future occupation? According to data accumulated, parents seem to be the most important influence on both sexes; they are closely followed by teachers. Friends and neighbors also exert strong influence (Beeson and Tope, 1928). It has been estimated that 61 per cent of adolescents follow the advice of parents, relatives, friends, and teachers (Peters, 1941).

In view of the strong parental influence, one might anticipate that many adolescents would follow the same vocation as their fathers. This expectation is not borne out. In one study of over 4,500 high-school students, only a small minority wished to follow their fathers' occupations. Most of the students selected work slightly higher in the occupational hierarchy than the father's trade (Kroger and Louttit, 1935).

ADULTHOOD

The years between the early 20's and the age of 65 are characterized chiefly by preoccupation with work and family life and by a narrowing of recreational activities. Participation in civic affairs often plays an increasingly important role. Success in any one of these enterprises depends largely on the training received during childhood and adolescence.

Work Life. As we have already seen, adolescents do have quite definite vocational preferences, even though they may not be in line with job opportunities or with ability level. Most adolescents also have some work experience, often gained through part-time or vacation jobs. However, the serious task of finding permanent work is left for postschool years.

At what ages do individuals in our society begin full-time jobs? The answer to this question involves regional differences. In one extensive survey in Maryland, it was found that 9 per cent of the 16-year-olds were already engaged in full-time work. This figure increased to 33 per cent by the age of 18, to 49 per cent by age 21, and to 56 per cent by the twenty-fourth year. Of the young people aged 24, another 5 per cent were doing part-time work, 20 per cent were homemakers, 2 per cent were students, 2 per cent were idle by choice, and 15 per cent were unemployed (Bell, 1938). Accordingly, we see that of this Maryland population the great majority were engaged in some kind of work by the age of 24. An interesting observation was made on the relationship between age of taking permanent work and father's occupation. About 45 per cent of the children of farm laborers, for example, had full-time work by the age of 16 as compared with 4 per cent of the children of technical or professional groups.

That the kinds of jobs taken by adults are not always what they want is dramatically illustrated in Table 27. According to this table, over 38 per cent wished to enter professional or technical fields, while only 7 per cent accomplished this. On the other hand, only 6 per cent wanted semiskilled jobs, but 25 per cent were forced to accept such employment. While this discrepancy was doubtless influenced to some degree by the depression, it holds even in normal times and indicates that many youths begin work under a handicap of disappointment.

Type of occupation is, of course, highly correlated with early education and training. In the Maryland survey, over 75 per cent of workers in the semiskilled, unskilled, and domestic-personal fields had only elementary-school education, whereas 90 per cent in the professional, technical, and office-sales areas had college education.

Given adequate abilities and motivation, most individuals gradually work up to more responsible and better-paid positions, up to a certain maximum. In a competitive labor market, however, this often involves considerable effort and study. Accordingly, work encroaches more and

TABLE 27. RELATIONSHIP BETWEEN PREFERRED AND ACTUAL OCCUPATIONS OF EMPLOYED YOUTH IN MARYLAND*

Occupational field	Per cent desiring	Per cent employed
Professional, technical..........	38.3	7.5
Managerial...................	9.1	4.1
Office, sales....................	18.5	27.1
Skilled........................	18.2	4.3
Semiskilled....................	6.3	24.9
Unskilled......................	2.5	14.6
Domestic, personal.............	6.9	11.4
Relief project..................	0.2	5.9
Other.........................	—	0.2

* From Bell, H. *Youth tell their story*. Washington, D.C.: American Council on Education, 1938. P. 132.

more on the individual's time and energies, so that recreation dwindles away to an all-time low as adult years slip by.

Age of Greatest Productivity. The age at which an adult achieves the most and/or greatest work depends largely on the type of work. Unfortunately, most of our data are limited to achievements in science and literature. The single available study of factory workers is based on a sample of 172 textile weavers, 127 spinners, and 147 nonferrous-metal workers. The investigators found no significant difference between productivity of older and of younger employees (Palmer and Brownell, 1939). However, as was noted in Chapter 6, older subjects work more slowly and output is accordingly lower, but the final product is often better and fewer errors are made. Furthermore, the greater stability of the older worker tends to compensate for decreased output.

Perhaps the most comprehensive survey of the relationship of age to productivity in science and literature is Lehman's (1936). He examined various histories and other source books listing the great contributions in various fields and studied biographical materials for data on total output of individuals, dates of birth and death, publication dates of various papers, etc. Since more men are alive at early than at later ages, he offset this factor by calculating average rather than total contributions of each age group. Two of the graphs based on these calculations are shown in Fig. 98. The striking feature of these illustrations is that the ages of greatest productivity in chemistry, mathematics, astronomy, physics, inventions, poetry, and short-story writing all occur relatively early in adult life—usually during the 30's

More recently, Lehman and Heidler (1949) submitted some detailed information regarding age changes in quality and quantity of literary out-

put, with quality tending to fall off much earlier than quantity. The time of greatest productivity of poetry was 25 to 29 years; of comedies and tragedies, 33 to 37 years; and of novels, somewhat later in the interval between 40 and 44 years. Great individual differences appeared, however,
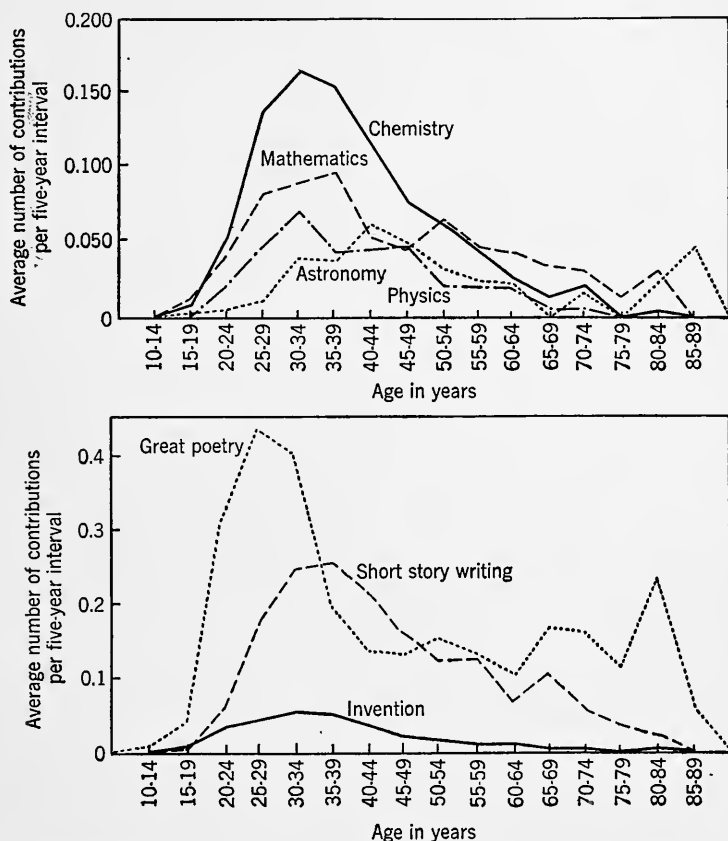
Fig. 98. Age trends in productivity in different areas of science and literature. (*After Lehman, 1936. From Kuhlen, R. G., and Thompson, G. G. Psychological studies of human development. New York: Appleton-Century-Crofts, 1952. P. 467. By permission of the publishers.*)

and for different individuals the best literary output might be found anywhere from the twentieth to the seventieth year.

For the group as a whole, the greatest achievements in both science and literature fall in the 30's. In other fields, the peak of accomplishment may be earlier or later. Leadership in government, education, religion, and defense, for example, come later. American college presidents are usually in their late 40's and early 50's, although some have achieved such positions earlier. Industrialists, prime ministers, cabinet members, presidents

of republics, members of Parliament or Congress, and religious leaders have been even older (see Miles and Miles, 1949). The ages at which man achieves the most feats—or, in the case of an *opus magnum*, the greatest—depend on the relative value of experience in a particular line of effort. George Bernard Shaw wrote masterpieces at an age when most men have long since abandoned all work; Mozart was composing music before most children begin school. Thus, while majority output falls somewhere within the adult range, the extremities of the distribution curve may extend well beyond adult boundaries in both directions.

Job Turnover. How does job turnover relate to age? According to available data, the periods of greatest turnover are the 20's and 40's, with the lowest turnover occurring between the ages of 26 and 40. The increased turnover after age 40 has been attributed to three factors: (1) general restlessness arising out of the changing physiological processes peculiar to this time, (2) termination of responsibility for rearing the family and paying for a home, and (3) recognition that if the job is not changed now it never will be (Kitson, 1925). As a fourth factor, we might well add restlessness due to unsatisfied ambitions and interests.

Job Satisfaction. Since work occupies so much of adult time, it is important to know how much satisfaction is derived from it. Some information is supplied by a study of over 1,000 men representing a cross section of the adult white population and involving nine occupational strata (Centers, 1948). The results are shown in Table 28. Perhaps the most interesting feature of this table is that not a single person in large businesses is dissatisfied with the job per se; almost the same situation exists in smaller businesses. In contrast to this, about one-quarter of the semi-skilled and unskilled workers are dissatisfied with their work. Although great individual differences are present in every stratum, it is encouraging to note that a majority within each occupation group is satisfied with the job and, in most cases, with other aspects of the work situation. For the over-all groups, business and professional men are happier in their work than semiskilled and unskilled laborers.

Age and Job Satisfaction. Studies on the relationship between age and job satisfaction yield contradictory results. Several investigators report no age trends; others have found older workers to be more satisfied than younger ones (see Kuhlen, 1945). Despite contradictions, it is clear that elderly workers are at least as satisfied as they were in earlier years.

Participation in Social Activities and Organizations. During school years, the individual gives little attention to activities outside the school. Gradually, however, he loses contact with schoolmates and becomes a part of the larger community group.

Social organizations are extremely numerous in the average American community. In one city of 100,000 population, over 500 such organiza-

TABLE 28. DIFFERENCES AMONG GROUPS OF VARIOUS OCCUPATIONAL STRATA WITH
REGARD TO SATISFACTION WITH VARIOUS ASPECTS OF WORK*

Occupational level	N	Percentage satisfied with			
		Job	Pay	Chances for advancement	Chances to enjoy life
Large business....................	54	100	66	87	94
Professional.....................	73	82	58	82	84
Small business...................	130	91	69	87	89
White collar.....................	165	82	50	61	82
Skilled manual..................	162	84	61	75	77
Semiskilled......................	172	76	38	52	69
Unskilled.......................	76	72	33	35	69
Farm owners and managers.......	151	95	46	80	80
Farm tenants and laborers........	66	85	52	68	75
All business, professional, and white collar..................	422	87	59	76	86
All manual workers..............	410	78	46	58	72
Total sample..................	1,071	84	52	69	79

* Modified from Centers, R. Motivational aspects of occupational stratification
J. soc. Psychol., 1948, **28**, 190.

tions existed, or roughly 1 for every 200 individuals. Of these, 65 were rec-
reational, 64 fraternal, 45 musical, 38 religious, 34 patriotic, 34 political
and governmental, 31 welfare, and 28 civic in character. In a smaller city
of 36,000 population, there were 458 active clubs, or 1 per 80 persons. This
abundance of social groups is characteristic not only of large cities but
also of small centers. In one rural community of 2,500 persons, for in-
stance, a total of 70 organizations not only existed but flourished, holding
well over 100 meetings every month (see Pressey *et al.*, 1939).

Although clubs and other organizations are numerous, many adults
make little use of them and participate in few or none at all. An extensive
survey in Minnesota revealed that 67 per cent of the adults belonged to
no organization, 78 per cent never attended club or lodge meetings, 75 per
cent failed to attend public lectures, and 81 per cent did not attend con-
certs. This picture characterized both urban and rural areas (Briggs,
1938). Thus it seems that the average adult is not especially interested or
active in many of the available organizations. However, socioeconomic
level is a potent factor in determining such activities. For example, in one
community, 92 per cent of the businessmen's wives belonged to one or
more clubs or lodges, while only 36 per cent of laborers' wives were mem-
bers (Lynd and Lynd, 1929).

Age and Participation in Social Organizations. Several investigators report on this topic. Mangus and Cottam (1941) studied the extent of social participation of Ohio farm people, basing their evidence on such items as attendance at meetings and membership in various local organizations. Their subjects appeared to pass through a cycle from inactivity through wide participation back to inactivity. The median participation scores were 4.9 for the 20- to 34-year-old group, 6.9 for the group 35 to 64 years, and 3.5 for those over 65 years. Other studies support the observation that middle-aged people are the most active joiners.

Marriage. As was mentioned earlier, marriage is the culmination of the heterosexual interests which emerge during adolescence. It has also been

Fig. 99. Age of marriage of husband and wife and success in adjustment. (*From Burgess, E. W., and Cottrell, L. S. Predicting success or failure in marriage. New York: Prentice-Hall, 1939. P. 117. By permission of the publishers.*)

noted that a considerable percentage of adolescents, especially females, are married by the late teens. Others follow during early adulthood, and by the age of 55, roughly 90 per cent of the adult population are married.

Various factors contribute to the making of a happy marriage. One of the more important is the happiness of the parents' marriages. If the parents of bride and groom respectively had a happy home life, the chances are high that their offspring will also have a happy marital relationship. That this does not invariably occur indicates that other influences also contribute. One factor is age at the time of marriage. Figure 99 graphically represents the correlation between age and success in marriage. Most outstanding are the great odds against the success of teen-age marriages. Almost half of the wives who marry before they are 19 make poor adjustments; husbands who marry under the age of 22 are a relatively poor risk. Couples in their late 20's show the best chance of good adjustment.

Another important contributing factor is illustrated in Fig. 100, which represents the relationship between the period of acquaintance prior to marriage and marital happiness. Contrary to the popular cliché that long courtships are undesirable, we see here that a brief courtship of 6 months or less is an extremely poor insurance against marital shipwreck. A long
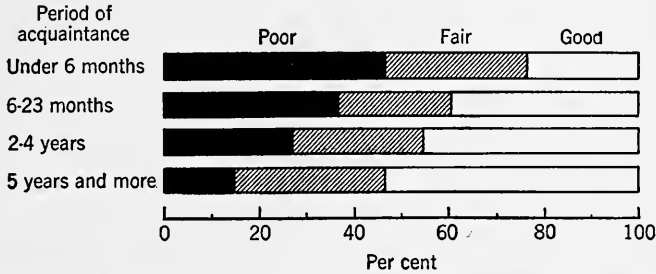
FIG. 100. Period of acquaintance before marriage and success of adjustment in marriage. (*From Burgess, E. W., and Cottrell, L. S.   Predicting success or failure in marriage. New York: Prentice-Hall, 1939. P. 165. By permission of the publishers.*)

acquaintance of 5 or more years affords a much better risk. In fact, the longer the courtship, the better the chances of marital happiness.

Happiness and Length of Marriage. Another popular notion is that most marriages are happy for awhile but that happiness begins to diminish as soon as the honeymoon is well over. Again, this layman's view is true only to a degree. Terman (1938) reported some relevant data based on a study
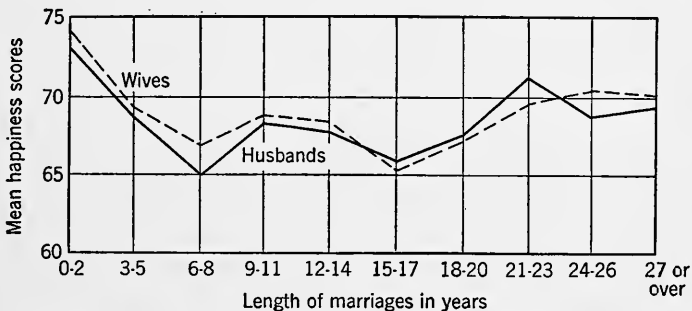
FIG. 101. Happiness as a function of length of marriage. (*From Terman, L. M.   Psychological factors in marital happiness. New York: McGraw-Hill, 1938, P. 177. By permission of the author and publishers.*)

of 800 couples. His results are shown in Fig. 101. This graph indicates that happiness is high for the first year or two, then declines rapidly to reach a low between 6 and 8 years after marriage. Following this early drop, there is some fluctuating improvement for the next few years, and finally there is a leveling off, so that after 20 years the couple is—and remains—almost as happy as in the first years of marriage. Terman believes that the low point at 6 to 8 years after marriage is due to waning of the honeymoon

and the presence of discord. The peak of the divorce rate, it is interesting to note, also occurs about this time. The other dips and increases in this curve are hard to account for in such a small sample.

OLD AGE

Many changes in social life come with old age. Under present conditions, most employees are retired from their accustomed jobs and must either remain idle or seek employment wherever they can find it. Children have grown up, married, and left home. One or the other of the spouses may die. We have already noted the various physical, sensory, intellectual, and emotional changes which limit the activities of the older person. We shall now look at some of the resultant social changes.

Role of the Aged in Different Cultures. The role played by senior citizens and the treatment they receive differ from culture to culture, varying from total neglect to high prestige. In some societies, they are considered a liability. The Eskimos, for example, used to leave the elderly behind to die —perhaps through economic necessity, for livelihood was so difficult that all members had to work in the interests of survival. A similar custom prevails in several African societies. In some other societies, however, the aged are venerated as chiefs and religious leaders. This high status is especially conspicuous in some Australian tribes in which the aged rule over the group, demand high respect, and are often feared. Here elaborate food taboos ensure that they receive the finer delicacies. In China, respect and reverence accrue to the aged, who are considered wise because of their great experience (see Gilbert, 1952).

In our own society, the attitudes toward the aged may generally be considered negligent and indifferent, although they vary from region to region. Old people are frequently sent off to an institution for the aged or, where these are unavailable, are settled in obscure rooms in the home of one of the children. Usually they fare better in rural areas, where they may continue to contribute more to the community and are more highly esteemed. In urban centers, especially in congested spots where living quarters are limited, treatment is inferior, to say the least.

This attitude of indifference toward the welfare of our seniors is deplorable today and, presumably, will become even worse as advances in medical science prolong the life expectancy. Since 1900, life expectancy has increased by 17.3 years for males and 20 years for females (Dublin, 1952). Because of this increase and the aging of the nation as a whole, the proportion of old people is steadily growing. In the United States, the total population increased 7.2 per cent during the decade from 1930 to 1940, while the number of persons over the age of 65 increased 35 per cent. As indicated in Table 29, the situation is not so different in England,

France, Sweden, and other such countries. Old people are becoming more of a social problem, especially from an economic point of view.

Work Life. One of the greatest trials of the later years is the loss of employment, which affects males more than females. The 1940 census provides the following data for the United States: between the ages of 60 to 64 years, 29 per cent were unemployed; at 65 to 69, 46 per cent; at 70 to 74, 64 per cent; and over 75, 83 per cent.

Termination of work not only results in idleness but may also precipitate other problems such as loss of economic security and personal status. Studies indicate that the majority deeply regret the cessation of work, and those who welcome retirement are less well adjusted than those who resist it (Cavan, 1952). Apart from the regrettable effects on the old people themselves, the fact that most people are retired during the early or mid-

TABLE 29. PERCENTAGE OF PERSONS 60 YEARS AND OVER IN SELECTED COUNTRIES, 1850, 1900, AND 1947*

Country	About 1850	About 1900	End of 1947
United States............	4.1	6.4	11.5
England................	7.2	7.5	15.2
France.................	10.1	12.4	16.0
Germany...............	7.0	7.8	13.8
Sweden................	7.8	11.9	15.3
The Netherlands...........	7.7	9.2	11.6
Denmark................	8.2	9.9	13.1
Norway................	8.8	10.9	13.7

* From Hauser, P. M., and Shanas, E. Trends in the ageing population. In A. I. Lansing, (Ed.), *Problems of ageing.* Baltimore: Williams & Wilkins, 1952. P. 966. By permission of the publishers.

dle 60's despite the lengthening life span poses the problem of providing adequate security in old age. Under existing conditions, elderly people are almost invariably forced to adjust to lower incomes and often to a change of residence at an age when it is increasingly difficult to adjust to change.

Problem of Retirement Age. At present it is common practice to retire employees around the ages of 60 to 65 years. This is often done without consulting the individual's wishes and without considering either his physical or his intellectual status. The popular view seems to be that when he reaches the 60's he suddenly becomes an inferior worker—considerably poorer, for example, than in the late 40's and 50's. As has been observed in earlier chapters, none of the experimental evidence on either physical or mental capacities supports the notion of any abrupt drop; when deterioration occurs, it occurs gradually. An even more important factor, however, is the differential rate of decline, which has been stressed throughout the

text. Well over 25 per cent of the elderly population surpass the mean per-
formance of young adults in both physical and mental performance. In
Chapter 10, it was pointed out that intellectual performance may show
little or no decline, especially in persons of superior intellectual ability.

Thus, all experimental evidence opposes the present system of estab-
lishing a fixed retirement age either in the 60's or at any other chronologi-
cal age. Undoubtedly there are many individuals who should be retired at
60 or even earlier, but there are also many who are physically, mentally,
and emotionally capable of working far beyond this age and who, under
existing conditions, are deprived of the opportunity to work. During
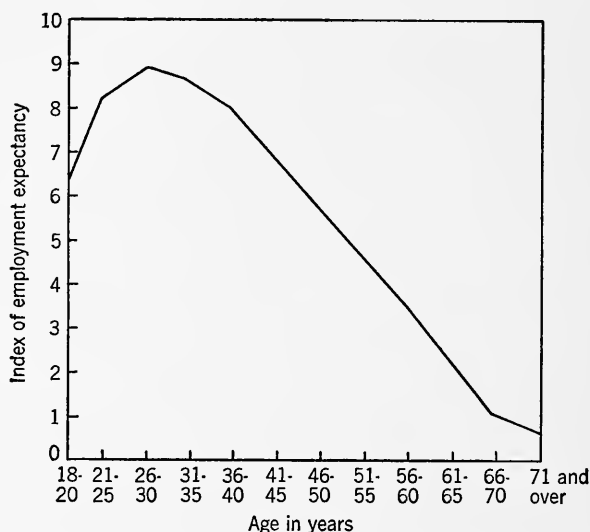
Fig. 102. The degree to which age is believed to be a handicap to employment as
viewed by personnel managers. (*After Casety. From L. A. Pennington and I. A. Berg
(Eds.), An introduction to clinical psychology. New York: Ronald, 1948. P. 220. By
permission of the publishers.*)

World War II, when demand exceeded supply in the labor market, we had
occasion to see how useful the elderly worker could be.

Age and Employability. Most employers will not hire workers much over
the age of 45. Figure 102 graphically summarizes employers' views regard-
ing the extent to which age is a liability or an asset. It can be noted that
from this viewpoint persons are considered good risks during the late 20's,
reaching a peak of employability around 30. From this point on, age
suddenly becomes a handicap rather than an asset. The drop in the curve
becomes especially pronounced after the age of 40 and by 60 years has
reached a low where it becomes almost impossible to secure employment.
In view of the scientific findings presented throughout these chapters, the
opinions prevalent among employers are most unfortunate.

Relation between Age at Retirement and End of Life Span. Another disturbing feature is the relationship between retirement age and death. Clague (1949) reports that around 1900 retirement preceded death by about 3 years. By 1940, this discrepancy had risen to 5.5 years, and according to Clague's estimates it will increase to 10 years by 1970. This points to two needs: (1) to find some way of extending the work span or otherwise to ensure adequate financial security for old age and (2) to find some way of encouraging people to develop hobbies or other activities early in life, so that the leisure hours may be profitably occupied when they grow old. Deep and abiding interests are rooted in childhood; trying to interest old people in new activities after retirement is difficult if not impossible (see Chapters 13 and 14).

Participation in Social Activities and Organizations. As we observed earlier, the highest incidence of joining various social groups occurs during the 50's. Perhaps the best evidence on later years is supplied by Cavan *et al.* (1949), who studied over 1,200 elderly people representing major religious groups in various areas of the United States. Table 30 summarizes the changes between the ages of 60 and 94 years. While 38 per cent of the 60- to 64-year-olds belong to two or more organizations, membership drops to 17 per cent by the age of 90 to 94 years. A similar age decline occurs for

TABLE 30. PARTICIPATION IN VARIOUS SOCIAL ACTIVITIES, BY AGE PERIODS*

Type of participation	Percentage of participation						
	60–64	65–69	70–74	75–79	80–84	85–89	90–94
Males							
Belongs to 2 or more organizations...................	38	34	35	32	16	21	17
Holds 2 or more offices.........	21	18	31	20	16	10	
Attends 2 or more club meetings per month..................	36	33	46	35	29	14	17
1 or more hobbies..............	60	66	70	64	52	37	60
2 or more future plans..........	65	52	62	49	43	35	
Females							
Belongs to 2 or more organizations...................	45	36	42	28	30	15	23
Holds 2 or more offices.........	23	17	13	6	4	23	
Attends 2 or more club meetings per month..................	52	39	41	39	33	29	29
1 or more hobbies..............	67	64	66	62	54	48	33
2 or more future plans..........	60	53	47	38	28	16	21

* From Cavan, R. S., Burgess, E. W., Havighurst, R. J., and Goldhamer, H. *Personal adjustment in old age.* Chicago: Science Research Associates, 1949. P. 50. Quoted by permission.

such activities as holding two or more offices, attending two or more club meetings per month, having one or more hobbies, and having two or more future plans. The trend is equally applicable to males and females.

Not only does actual participation decrease with age, but the attitudes toward participation also change. Cavan *et al.* noted that favorable attitudes toward clubs, lodges, and other organizations—that is, deriving stimulation from such social groups and in general being interested in them—decrease from 50 per cent in females in their 60's to 9 per cent in the 90's. This decline is accompanied by a diminishing feeling of satisfaction with leisure in general. Males evidence a similar but less marked change.

Although these data point to a considerable drop in social-activity level in old age, it should be noted that here as elsewhere a fairly high percentage of even the oldest individuals continue to participate. The degree of participation undoubtedly depends on several factors. Fried (1949), for example, reports a correlation between socioeconomic status and degree of participation. People in the upper socioeconomic brackets are roughly six times as active as those of the lower levels. We might wonder whether old people who lack economic security lose interest in social groups because they cannot afford to participate.

So far we have been concerned solely with group aspects of social behavior. Other activities such as radio listening, reading, attending movies, and hobbies will be discussed in the next chapter.

Family Life. The declining years are characterized by the absence of children and often by loss of the marital partner. Since the life expectancy of women exceeds that of men by several years, and since women customarily marry younger than men, it is usually the female who is left alone in old age. In 1948, for instance, the life expectancy of males was 65.5 years in the United States; for females, 71.04 years (Dublin, 1952). Consequences of this differential longevity are shown clearly in the census figures for 1940. According to these figures, 11 per cent of males aged 60 to 64 and 59 per cent aged 85 and over were widowers. The more drastic situation of females is revealed when we note that 31 per cent are widowed by the age of 60 to 64 (male 11 per cent) and 85 per cent at 85 years (male 59 per cent).

Since remarriages are rare in old age, the widow and widower may feel the loss of affectional relationships keenly, especially if no children or relatives remain in the vicinity and if a close husband-wife relationship had prevailed in earlier years. It has been reported that the surviving spouse may withdraw into seclusion, idealizing the deceased, and may become quite hostile to relatives and friends (Stern *et al.*, 1951). On the other hand, the lone widow or widower may become overdependent and cling too closely to offspring or other associates.

DEVELOPMENT AND CHANGE OF INTERESTS

This chapter is concerned with some of the variables which affect interests and with the resultant changes in interests throughout the life span. What do people of different ages read or talk about? What radio programs and movies do they prefer? Perhaps no aspect of behavior contributes so much to our understanding of either an individual or a society as a knowledge of what people like or voluntarily choose to do. Attending movies, listening to the radio, watching television, or reading books, journals, or newspapers are powerful factors in determining motives, values, beliefs, attitudes, and personality characteristics, for all of these are communication media designed to inform and to channel the tastes of the public. Thus, a study of the nature and strength of interests of various age groups tells us what aspects of the environment they are exposed to and indicate what stimuli influence them. Obviously, such stimuli are especially important during the formative years of childhood and adolescence. They influence adjustment even during the later years, however, and, on the other hand, reflect the adjustment patterns already crystallized.

CHANGES IN INTERESTS DURING CHILDHOOD AND ADOLESCENCE

Studies of child and adolescent interests are so numerous that we cannot hope to summarize them even briefly. Accordingly, we shall select only the more important investigations, especially those which give a clear picture of major age trends. The discussion will be oriented around general interests and followed by a brief treatment of such special topics as reading content and radio and movie preferences.

Some General Interests: Play, Collecting, and Conversation

Interests Revealed in Play. Play activities reflect interests at any age. One of the earliest evidences of interest is the infant's exploration of his own body—apparently to find out what the body parts are capable of doing. During the first 3 months, he seems to derive considerable satisfaction from playing with his own arms, feet, and fingers. As motor coordination develops to a level at which he is able to reach out and grasp ob-

jects, this preoccupation with his own physical equipment declines. Instead, he begins to show interest in things, throwing objects about or banging them against floor or furniture.

It is only after the first year of life that the child engages in activities which we call "play." During the first year, he explores toys and other objects extensively by shaking, pulling, pushing, feeling, and even sucking them to find out what they are and how they work. This phase is gradually replaced by a more constructive one of playing with blocks, building towers, houses, or trains. Balls, toy cars, dolls, and other manufactured toys increasingly hold his attention.

As childhood merges into adolescence, the all-absorbing interest in toys is replaced by greater enthusiasm for games and sports, although a child may continue to cling to a favorite toy for sentimental reasons. Both sexes actively engage in games and sports throughout middle childhood and early adolescence. Toward the end of adolescence, however, this interest shifts from the active to the passive, and the average boy or girl derives more enjoyment from spectator sports than from active participation.

General Interests and Recreations. Much information concerning the nature of interests may be obtained by simply asking people to state their likes and dislikes. In one extensive study of well over 4,000 children and young adults from grade 6 through college, subjects were given a long list of activities and requested to check those items in which they were interested and to double-check those of special interest. The results for both sexes are shown in Fig. 103.

The most striking feature of Fig. 103 is the trend toward decline of certain interests as others emerge. Boys in grades 6 and 7, for example, are highly interested in such gross motor activities as horseback riding, fishing, cycling, and roller skating. These preferences diminish rapidly, reaching a low during college years. On the other hand, interests of a social-sexual nature such as dancing, dress, and social gatherings begin to gain ascendancy in junior high school and become more and more important with advancing age. In general, the developmental picture is the same for both sexes, although girls are less active than boys at any age represented in this figure. Furthermore, in line with their earlier physical maturation, girls evidence social-sexual interests sooner than boys. In summary, we may say that interests of an active type decline with age, while those of a social-sexual type increase.

Interest in Collecting. Children begin to collect and hoard objects at an early age. The shocking contents of the little boy's pocket have been noted by poet as well as psychologist. During early years, children indiscriminately accumulate anything which attracts even temporary attention. At 3 and 4, these items are more often than not trivial and useless. Once assembled, they are soon forgotten. As youngsters approach school age,

collecting is intensified but also undergoes a certain degree of refinement. The peak of collecting activity is reached by boys at 10 years and by girls at 11 years. For both sexes, collecting interests begin to wane after the age of 14. Girls tend to collect more than boys (Durost, 1932).

Conversational Interests. What do children of different ages talk about when they are together? Conversation of nursery-school children invariably revolves around themselves and their activities. If the second person
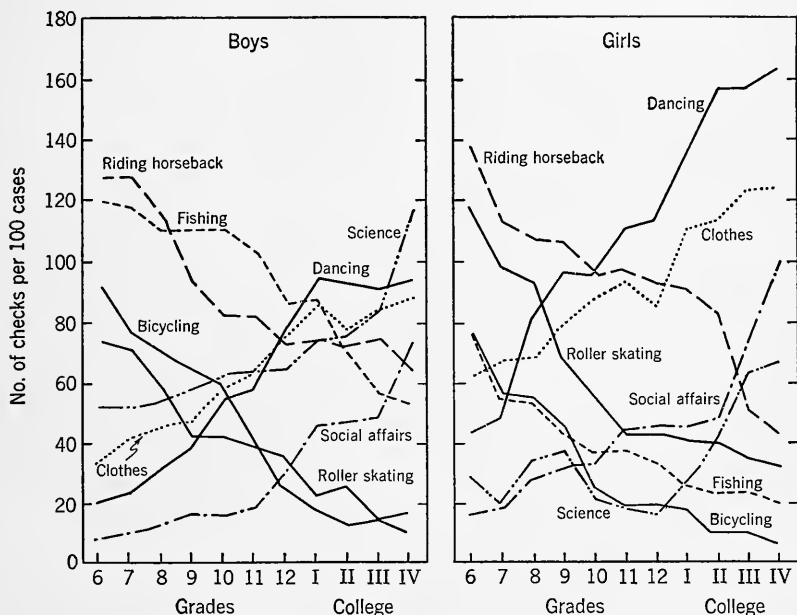
FIG. 103. Changes in interests and recreations through adolescence. (*Based on unpublished data of Pressey. From Kuhlen, R. G. The psychology of adolescent development. New York: Harper, 1952. P. 193. By permission of the publishers.*)

is brought into a conversation, it is usually as the object of a command (Sprague, 1929).

As might be anticipated this emphasis on self diminishes with age. One teacher, who eavesdropped on the recess conversations of children grades 3 to 6 for a 6-week period, reported the five favorite topics in rank order: (1) sports, (2) personal experiences, (3) trips, (4) pets and their tricks, and (5) family members and friends. In general, the younger children covered a wide variety of topics, while the older ones narrowed their range of interests, talking less of family matters but more of school activities, movies, etc. (Dawson, 1937).

When high-school boys were asked, "What are the topics most frequently talked about among boys?" those in grades 9 to 12 reported a progressively increasing interest in sports and games, girls, social ac-

tivities such as dating and having good times, sex, and "dirty jokes." Discussions of family matters and of personal possessions were few (Fleege, 1946).

Surveys of conversational topics of late adolescents and adults reveal a content similar to that of high-school students. Investigations of conversations held in railway stations, restaurants, theaters, streetcars, and other gathering places indicate that conversations relate to money, sports and other amusements, persons of the opposite sex, and clothes. As we might expect, sex differences are marked. Men talk most about business and amusements; women, about clothes and other women (Landis and Burtt, 1924).

Reading Interests

An interest in reading far antedates school age. As early as the third and fourth years, children like to flip through books containing large, brightly colored pictures of animals or people and enjoy hearing simple stories about these pictures. During the preschool years, they particularly enjoy stories of animals such as "Peter Rabbit" or "The Three Bears." They like these animals to speak and act like people. Simple fairy tales and stories like "Little Red Riding Hood," "Cinderella," or "Little Black Sambo" are popular (Witty *et al.*, 1946).

Interests during Early School Years. Studies indicate that most children reach the age of reading readiness during the seventh year. While learning the rudiments of reading, they continue to be interested in books with many colored illustrations, preferably about such topics from nature as storms or wind, trees, or animals. Fairy tales are not very popular at this time, but regain their appeal to become favorite reading during the eighth year. Stories of children of foreign lands are also liked by the 7- and 8-year-olds.

The ninth and tenth years are marked by two developments. First of these is the permanent decline of interest in fairy tales and stories of a make-believe character; second is the initial appearance of sex differences. Boys become more interested in tales of adventure and mystery and in stories of science, building things, and school activities. Girls continue to be interested in fairy tales and animal stories but show increasing liking for romance and for plots with domestic content (Terman and Lima, 1927). Despite this incipient divergence, the interests of the two sexes overlap greatly. In general, girls read more boys' books than boys read literature designed for girls. Interestingly, this sexual transgression occurs more frequently among the brighter girls and the duller boys (Lazer, 1937).

"Reading-craze" Period. The period of greatest reading activity occurs between the ages of 12 and 13 years (Terman and Lima, 1927),

when both sexes read any available literature. Since this period is characterized by hero worship, biographies of great men and women and stories of legendary heroes have special appeal. Adventure, travel, and mystery tales continue to be popular, however.

An important characteristic of this heightened reading activity is its purpose: it is done "just for fun." From preadolescence to maturity, however, reading for sheer amusement declines sharply. Undoubtedly this decline is a result of the decrease in leisure time, in turn caused by the great number of adolescent social activities (Lehman and Witty, 1927b). Homework is also a factor. This is supported by the finding that reading for the purpose of acquiring knowledge increases during the teens. One investigator reports the median number and type of books read by students of different ages. According to his study, students of the reading-craze period average 31 volumes of fiction, while students aged 17 read only 7 books of this kind during the year. In contrast to this picture, non-fiction reading increases from 2.5 to 6 volumes over the same period (Eberhart, 1939).

In addition to the drop in amusement reading, another developmental trend emerges during the teens—a trend toward greater selectivity. Whereas late childhood is characterized by widespread reading of everything available—a sort of sampling procedure—adolescent reading interests are narrowed down and channeled. Individual differences become more marked. Some teen-agers prefer adventure or mystery, others science, and still others romance. The interest in specialized topics is particularly noticeable around the age of 16, when adult reading habits are achieved (Terman and Lima, 1927).

Favorite Reading Topics of Adolescents. As has already been noted, one of the characteristics of adolescence is the desire to read only topics of special interest. The choice of topic varies with age and sex. From the age of 14, the boy's acute interest in adventure is gradually superseded by a liking for mechanics, scientific inventions, and sports; at 15, his main interest is in technical books concerning hobbies; and at 16, in informational reading and current events. Romantic stories do not become popular with boys until late adolescence.

Around puberty, girls develop increasing preference for romantic literature, and by the age of 14 most of them are reading love stories—either openly or surreptitiously. They also like historical novels, adventure stories, and novels with elements of romance. Informational reading takes second place to fiction. Poetry and plays are liked by most girls (Terman and Lima, 1927).

Magazines. Older children read more magazines than books. Undoubtedly several factors determine this preference: cheapness, abundance of such literature, and the ample illustrations which are usually absent in

teen-age books. Roughly 12 per cent of grade-5 children read magazines as compared with 75 per cent of grade-12 students (Brown, 1939).

Boys look for articles dealing with science and mechanics, athletics, adventure, and G-men. On the other hand, girls concentrate on magazines or sections of magazines involving true-life stories, anecdotes about movie stars, and features on fashions and etiquette. Both sexes read sections concerning current events, adventure, humor, and continued stories.
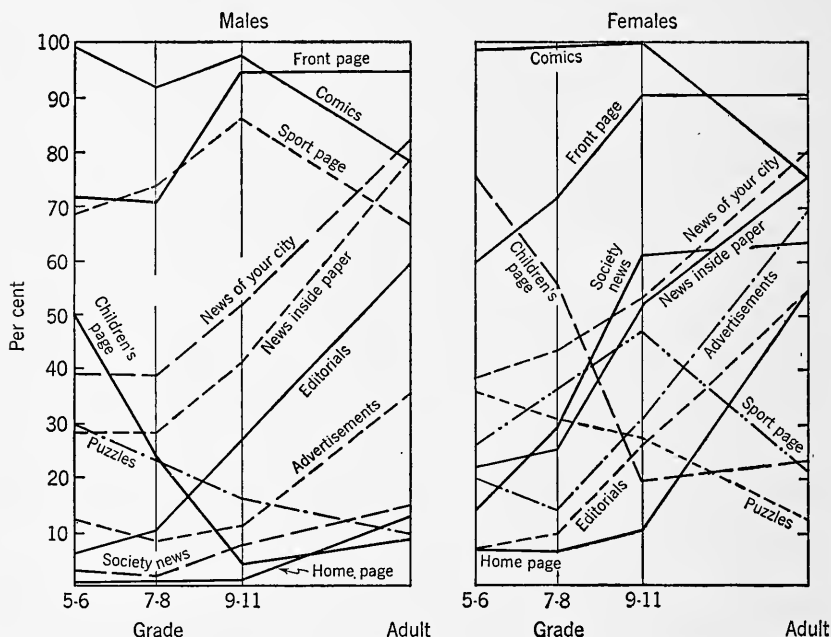
FIG. 104. Percentage of children in different grades and of adults of each sex who usually read various sections of the newspaper. (*Based on data of Johnson. From Kuhlen, R. G. The psychology of adolescent development. New York: Harper, 1952. P. 199. By permission of the publishers.*)

Newspapers. Like magazines, newspapers are read chiefly by the older children and adolescents, although the comic strips are popular at an earlier age. As everyone knows from personal experience, however, not all sections of a newspaper are of equal interest at any age.

Figure 104 illustrates the percentage of individuals of various ages who read certain newspaper sections. Perhaps the most striking fact is that all individuals, male and female, from grade 5 to adulthood, read both the comics and the front page. Most males of all ages read the sports page. The inside news pages, editorials, and advertisements are rarely noted by children in grades 5 to 8 but become progressively more popular until adulthood. All adults read—or at least look at—these sections.

Radio Interests

Excluding television, which is still in its infancy, perhaps radio has become one of the more popular of indoor amusements at all ages. Even young children listen to a variety of programs. The importance of this communication medium becomes clear when we note that between 91 and 98 per cent of all American homes have at least one radio. Furthermore, studies show that children aged 9 to 12 spend 2 hr. per day listening to the radio; children aged 12 to 15, 2½ hr. No sex differences appear. As we might expect, rural children spend more time in radio listening than urban children, the ratio being 18½ to 13 hr. per week (Clark, 1940). To appreciate the significance of this time element, we must remember that school-age children have limited time for extramural activities.

Most children devote much more time to radio listening than to either leisure reading or movies. Thus, radio programs probably affect children more than many of the other communication media such as crime comics or movies, so frequently attacked by the public.

Program Preferences. Children and adolescents of all ages listen to all kinds of radio programs, the choice depending chiefly on the hours when the children are free. When confronted with a list of programs, they do have preferences, however. Kindergarten as well as first- and second-grade children like "The Lone Ranger," "Dick Tracy," Jack Benny, and a variety of musicals (Wilson, 1941); few enjoy educational programs. In general, girls have a wider range of program interests than boys (Hockett and Fick, 1940).

Some idea of the developmental trend in program preferences is shown in Table 31. This table summarizes the responses of 2,500 boys and girls, grades 5 through 12, who were requested to "check each of the types of radio programs to which you enjoy listening." According to this survey, mystery and detective plays are especially popular with grade-5 youngsters. Comic dialogues, skits, and dramatic plays are also enjoyed by both girls and boys at this time. While the liking for mystery and detective plays declines with both sexes, especially girls, the interest in dramatic plays and comic skits continues. The increasing interest in social activities is reflected in a growing preference for dance music and song hits. In keeping with earlier physical maturation, this preference appears earlier in females than in males. Interest in political events, news features, and classical music is negligible in the lower age groups but increases during the adolescent years.

Effects of Radio Listening. It has been demonstrated that certain radio programs have a disturbing effect on children. Listening to crime and horror stories increases nervousness in both quantity and intensity and produces sleeplessness, disturbances in eating, nail biting, and increased

fears (DeBoer, 1939; Preston, 1941). Sleeplessness and nightmares are especially common among children under 12 years of age who listen to such programs. Both sleep disturbances and nightmares are more prevalent among rural than urban children (Clark, 1939).

TABLE 31. TYPES OF RADIO PROGRAMS LIKED BEST BY BOYS AND GIRLS AS SHOWN IN PER CENT LIKING AT DIFFERENT GRADE LEVELS*

Type of program	Boys				Girls			
	5th	8th	10th	12th	5th	8th	10th	12th
Mystery and detective plays......	94	94	85	67	97	95	76	39
Comic dialogues and skits........	86	92	88	77	96	88	93	78
Dramatic plays..................	88	83	67	55	90	85	86	90
Popular dance music.............	47	63	83	94	70	81	95	99
Popular song hits................	45	52	78	70	54	60	81	82
Semiclassical music, orchestra and band........................	44	78	11	17	60	81	57	32
News, including sports...........	12	47	55	55	46	31	53	26
Political speeches................	7	46	51	45	2	20	33	18
Classical music, including opera...	6	16	12	11	10	25	23	20
Educational talks................	1	11	22	13	4	8	8	13

* From Brown, F. J. *The sociology of childhood.* New York: Prentice-Hall, 1939. P. 328. Quoted by permission.

Movie Interests

Attending movies is one of the best-liked forms of entertainment, ranking well above radio with many children. Most youngsters prefer movies to either games or reading (Seagoe, 1931). Some idea of the popularity of movies is revealed in a study of 20,000 individuals ranging in age from preschool to late adolescence. Among other things, the subjects were asked how frequently they attended movies. According to their responses, 55 per cent of boys and 45 per cent of girls aged 5 to 8 years went to the movies at least once a week. By the late teens (17 and 18), 75 per cent of both sexes attended at least once a week and 25 per cent twice a week or more. The percentage who never attended movies ranged from 8 to 2 per cent for boys and from 12 to 2 per cent for girls for ages covering early childhood to late adolescence (Dale, 1935). These data tend to emphasize the considerable role which movies play in the life of children.

Preferences. What type of movies do individuals at these age levels enjoy? In general, preferences parallel reading interests, except that comedy rates higher in movies than in literature.

Among young children aged 5 to 8, animated cartoons and comedies are the most popular, especially if child actors or animals play the leading

roles. These youngsters want their heroes to be active and their heroines to be beautiful (Seagoe, 1931). Beyond these ages, preferences change and sex differences appear. During middle childhood, boys rank westerns and swashbuckling adventure pictures at the top of the list, with comedy a close third; girls also place westerns at the top, but this preference is less intense than among boys. Among girls, comedy and romance rank second at this time (Mitchell, 1929).

As childhood merges into adolescence, preferences change again. One of the most characteristic age trends is a decreased interest in westerns among both sexes. Among girls, romantic movies soon predominate over other varieties. Comedy and historical films are also acceptable but rank well below the romantic pictures. Boys' interests, on the other hand, spread equally over films based on adventure, comedy, history, sports, and mystery but exclude romance. Movies of an educational nature or pictures dealing with war or tragedy have little appeal for either grade-school or adolescent youngsters of either sex (Mitchell, 1929).

Influence on Behavior. Since the advent of movies, investigators have been interested in their effects on children of various ages, and studies in this field are numerous (see Hurlock, 1949). These explorations indicate that the effects on younger children are chiefly physical, taking the form of increased restlessness during sleep and changes in pulse rate and respiration after certain types of movies have been seen. At later ages, especially among girls, the influences appear to be reflected more in attitudes and views. Girls regard movies as a source of information on good grooming—make-up, hairdress, and fashions—and on the correct thing to do on various social occasions. Both boys and girls view movies as an authority on how to deal with the opposite sex—a veritable combination of Dorothy Dix and Emily Post. Movies also tend to encourage a desire for travel, adventure, and wealth.

Variables Affecting Interests

The discussion so far has been concerned primarily with major age trends. Apart from age, however, there are many variables which determine interests at any time of life. It has already been noted, for example, that there are marked sex differences in interests. Let us look briefly at a few others.

Physical Development. The individual's physique and physical capacities go a long way toward determining his interests. This is most evident at the two extremes of the life span. During infancy, the child begins to play with toys only when muscular coordination has developed sufficiently to enable him to grasp and manipulate objects. An interest in tricycles appears about the time that locomotor activities have become fairly well developed. Around puberty, the keen application to strenuous

sports is correlated with the growth spurt in the skeletomuscular systems. Sexual maturation is accompanied by heightened interest in social-sexual relationships involving dancing, romantic movies, band music, and clothes. At the other extreme, as we shall see shortly, the older individual prefers sedentary activities to the more highly active.

Intelligence. It has been demonstrated by a number of investigators that an individual's intellectual status also influences his interests. For example, one extensive study comparing mentally superior with mentally retarded children in 310 communities in 36 states revealed that the superior children showed greater interest in study, dramatics, religious activities, scouting, and campfire work. Furthermore, roughly 12 times as many retarded as superior children had no hobbies, and evidenced less interest in both active and sedentary occupations (Lewis and McGehee, 1940).

Research on reading interests shows the correlation between intellectual ability and interests even more clearly. One investigator found that the age of appearance of certain interests depended on intelligence. The bright children, for instance, showed a maximal interest in realistic animal stories between the ages of 9 and 11; the dull children, between 12 and 14. Reading of romance reached a peak at 12 to 14 years in bright children and after 14 in the dull group (Thorndike, 1941). These findings appear logical and have probably been noted by most careful observers.

From a survey of other studies, it appears that bright children of any age select a wider variety of radio programs, show greater appreciation of humor in radio programs, collect items of a more complex nature, have more hobbies, engage in more activities which involve thinking, read more widely, and choose reading of a more realistic nature and of higher quality (see Kuhlen, 1952a).

Environment. Apart from physical and mental equipment, the individual's interests are determined by his environment. Since he must adapt to his surroundings, to some degree, it is to be expected that likes and dislikes of rural children will differ to some extent from those of their urban peers, that children who live near the seashore will differ from mountain or prairie youngsters, and that socioeconomic status will play a role in determining whether they can afford to join clubs, attend movies, or buy books. Location and socioeconomic status also influence choice of friends, and all of us are influenced by our associates. This is especially true of late middle childhood and adolescence, when the peer group is so important.

INTERESTS DURING ADULTHOOD AND OLD AGE

So far, we have found that adolescent interests are social in nature, in regard both to activities such as reading or movies and to other entertain-

ment. What happens to these interests as the individual enters the workaday world where he must fend for himself? How do they change as he advances through adulthood to old age?

Numerous investigators have attempted to answer these questions (see review by Kuhlen, 1945). Age changes reported are difficult to interpret, however, since most of the studies are cross-sectional rather than longitudinal, *i.e.*, they deal with various age groups instead of following the same subjects throughout the years. Thus, social conditions as well as the individual himself change, and it is hard to segregate the variables. Such difficulties of interpretation are well illustrated in the following tentative conclusion based on such data: Old people attend movies less frequently than young people. Although this statement is true and may reflect a decrease in movie interests with age, it is also true that present-day old people had no movies to attend in their young days and consequently established no such habit. Thus cross-sectional studies cannot tell us what present-day adolescents will be like when they reach old age.

These difficulties in interpretation should be kept in mind throughout this and subsequent chapters. It is likely that technological and social changes influence interests more than any other phase of development discussed in this book, however. While studies of interests are hampered by difficulties both in gathering and in interpreting data, nevertheless they do give a fairly accurate picture of developmental changes. Basic trends do not change from one generation to the next, even though the superficial expression of interest patterns may depend on the social and technical facilities at hand. Grandfather may have lived in the horse-and-buggy days while grandson drives an automobile, but the purposes of these conveyances remain constant.

General Studies of Interests. Perhaps the most extensive investigation of age changes in interests during adulthood was carried out by Strong (1931, 1943). The Strong Vocational Interest Blank was given to 2,300 professional men ranging in age from 20 to 60 years. This blank consists of 420 items dealing with occupations (*e.g.*, architecture, teaching), activities (*e.g.*, repairing the radio), school subjects (*e.g.*, algebra), amusements (*e.g.*, tennis, fishing), peculiarities of people (*e.g.*, energetic, exuberant), and various other topics. All subjects were asked to indicate whether they liked, disliked, or were indifferent to each item.

Analysis suggested that older men have as many likes and dislikes as their juniors but that the nature of the likes and antipathies differs for the two groups. Some of the age differences are summarized in Fig. 105. Perhaps the most noticeable changes are in physical skills and daring, for example, in driving automobiles, playing tennis, or climbing along the edge of a precipice. Such activities reach a peak at 25 years and lose their appeal fairly early. On the other hand, interest in such passive pursuits as

observing birds, raising flowers and vegetables, visiting museums, or reading increases with age. According to Fig. 105, liking for various social activities such as attending bridge parties, smokers, and full-dress affairs and entertaining others declines with age to be replaced by an increasing preference for more nonsocial activities. Thus, older people prefer reading books to attending movies, would rather chat with a few intimate friends than with many acquaintances, and spend more time at home than formerly.

Other age changes have also been noted. Ranking high among them is the elderly person's resistance to change and to interference with regular
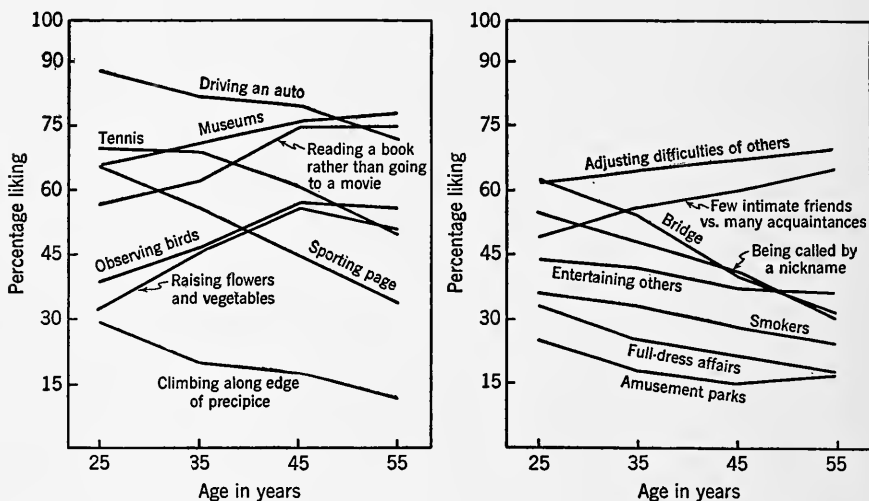
FIG. 105. Age changes in certain amusements (left graph) and social interests (right graph). (*Based on data of Strong. From Kuhlen, R. G., and Thompson, G. G. Psychological studies of human development. New York: Appleton-Century-Crofts, 1952. Pp. 282, 283. By permission of the publishers.*)

routine. Older people prefer a steady job to changing jobs, working in the same location to different locations, regular hours to changing hours, and noncompetitive to competitive activities. They become increasingly intolerant of people with undesirable characteristics and have less interest in such creative work as writing articles, books, or poetry. Thus it appears that the keen enthusiasm for physical and social activities so characteristic of adolescence gradually diminishes during the later years. Essentially similar results were obtained in another study of business and professional people (Thorndike, 1935).

Interests of Eminent People. What interests characterize the eminent members of our society? To answer this, questionnaires were sent to a large number of persons listed in *Who's Who in America*, 1946–1947, and to

other distinguished citizens. More than one-half of the subjects were over 75 years of age. Generally speaking, their interests paralleled those of business and professional people, discussed above. The subjects expressed great liking for reading, gardening, observing birds, and visiting museums and art galleries. In contrast to their noneminent contemporaries, however, they continued to be interested in a variety of social activities such as clubs, civic organizations, and bridge games as well as in physical activities such as golf and creative enterprises such as writing. These eminent subjects also had a wider range of interests. Anywhere from 3 to 10 different interests were held by 72 per cent of the group and more than 10 interests by 13 per cent. The average number of well-developed interests for the total sample was 6 (Chandler, 1950).

Interests of General Population. The studies discussed above dealt with a select population of superior socioeconomic status. What comparable data are available concerning age changes in the general population?

Probably the best study is that of Briggs (1938), who interviewed 1 out of every 500 adults in the state of Missouri, taking care to obtain representative samples of both urban and rural areas and also to include the various occupations. Interest changes as revealed in this survey are similar to those of business and professional groups studied elsewhere. Participation in sports, attending movies and dances, entertaining, and playing cards all decreased with age. Attendance at lectures, concerts, and church showed little change between the ages of 25 and 50. Such nonsocial activities as flower gardening, visiting museums, reading, and other cultural pursuits increased with age (Kelly, 1935; Hall and Robinson, 1942).

Hobbies. One of the major needs of our senior citizens and especially of those past retirement age is the need for hobbies. Evidence now available indicates that only 45 per cent of 20-year-olds have hobbies. This percentage decreases during the working years up to age 50 and subsequently increases again to reach 95 per cent between ages 65 and 75 (Briggs, 1938). The scarcity of hobbies in early maturity is undoubtedly due to preoccupation with economic and family matters. As retirement approaches, people again turn to avocational pursuits. Beyond the age of 75, interest in hobbies declines, and only one-third of the population report such activities. This drop is presumably associated with physical deterioration, especially of sensory functions.

Apart from the age variable, other factors also affect interest in leisure-time pursuits. The most important such factor is education. One investigator reports that, of his elderly subjects with less than 4 years of formal schooling, only 21 per cent had hobbies as compared with 54 per cent of those at high-school level and 64 per cent of those at college level. In addition, persons residing in urban areas had more hobbies than those in rural areas. No sex differences were noted (Briggs, 1938).

Conversational Interests. It has already been observed that adolescents and young adults converse chiefly about people, sports, and a variety of sex-social activities. Unfortunately, data concerning conversational topics during the later years are almost negligible. We have a few suggestions from a study of the nature of conversations in a mountain community in Oregon, however. This group included about 1,000 subjects. One of the interesting findings was that talk about people was the favorite, showing no decline from adolescence through to old age. Similarly, egocentric speech about oneself and one's work was the favorite at all ages, especially after the age of 40. Conversations about religion, politics, and economics as well as reminiscing were rare during the teens but increased progressively thereafter until in extreme age they practically monopolized all conversation (Hall and Robinson, 1942).

Reading Interests. Reading is a favorite pastime with adults as well as with children. It is generally agreed that it becomes progressively more popular throughout adulthood and old age at the expense of the physical activities (Kelly, 1935; Strong, 1943; among others). Accompanying increased interest in reading is an improvement in the quality of material read (Hall and Robinson, 1942).

This increase in reading interest must be qualified, for it applies to only certain kinds of material. Reading books reaches a peak between 20 and 30 years of age, when over two-thirds of the population read them. During the 30's, book reading begins to decline, and beyond the age of 60, only 40 per cent report such activity. However, this decline is more than compensated for by the rapid rise in magazine and newspaper reading (see Kuhlen, 1945).

Books. Although book reading drops from 67 to 40 per cent between the ages of 30 and 60, many older persons continue to enjoy books. The decrease is accounted for by the drop in fiction reading. Nonfiction increases steadily in popularity from 20 to 60, and perhaps beyond this age (Thorndike, 1935; Allard, 1939). Of nonfiction books, such topics as improving oneself, biography, farm life, and government had special appeal for elderly people in one rural community (Hall and Robinson, 1942). Unfortunately, data are lacking on urban areas.

Newspapers and Magazines. Although over-all newspaper reading increases with age, certain sections of the daily newspapers are preferred to others. Figure 104 indicates that comic strips, sports, and the front page are best liked by children and young adults. In the subsequent years, the front page continues to be popular, but the interest in comics, cartoons, and the sports page declines sharply. On the other hand, the inside news pages, advertisements, and editorials rarely read by children become more and more popular with advancing years. Other sections which grow in appeal are letters to the editor and features dealing with politics, religion,

and health (Schramm and White, cited by Shock, 1951; Hall and Robinson, 1942).

Sections of magazines enjoyed most in later life are similar to the newspaper features discussed above. Health, politics, and religion are well liked. Articles about children and stories of adventure are also preferred (Hall and Robinson, 1942).

Interest in Radio. Nationwide surveys indicate that in American homes the radio is tuned in for an average of 3 hr. or more every day. The amount of listening depends on several variables, the middle socioeconomic group, for example, listening the most. A relationship also exists between education and radio-listening time. People with an elementary level of education average 22 hr. a week, while those with college education average 17 hr. (see Cantril and Allport, 1935). Besides socioeconomic status and education level, age constitutes a third variable, since listening time decreases with the years, especially beyond age 40 (Lazarsfeld, 1940).

Another interesting observation concerning radio listening is that over two-thirds of young adults below 30 years tune in stations blindly, while older adults select their programs in advance. The majority of elderly listeners restrict themselves to a maximum of three stations (see Cantril and Allport, 1935).

Program Preferences. What kinds of radio programs are preferred by the vast radio audience? Cantril and Allport (1935), who summarized much of the research on this topic, report that young adults under 30 years of age rank dance orchestras and sports in top place, while adults over 30 give old song favorites, humor, and news the top priority. Other programs enjoyed by the older audiences are drama, opera, and talks on educational and political matters.

The type of music preferred by various age groups was extensively explored by the Iowa Survey of 1942 (see Lazarsfeld and Stanton, 1944). The four categories used were classical, popular, band, and old-time and religious. Popular music was favored until the age of 50, after which religious and old-time music quickly replaced it. In general, classical-music programs were lowest on the list for all age groups, although people in the higher educational brackets tended to rate it high at all ages.

Interest in Movies. The movie industry is undoubtedly the most highly commercialized form of entertainment today. Public appeal is so great that during early life movie attendance is almost universal. However, attendance drops off quickly in later life. At the age of 35, only 60 per cent go to the movies; at 50 years, 40 per cent; and at 70 years, less than 20 per cent (Briggs, 1938).

Some idea of developmental changes in interests in this respect is shown in a study by Edman (1940), who compared the attendance habits of adolescents and adults over a 5-month period. Adolescents, as has already

been indicated, preferred comedy, farce, and romance. This liking was shared only in part by adults, who continued to enjoy romantic films but not farce or comedy. To replace these, historical and social drama as well as dramatized novels gained in popularity. Other differences emerged. Well over 30 per cent of the adolescents attended movies just to "kill time," and over 20 per cent did not even bother to see what film was being shown. Adults were much more discriminating; less than 10 per cent attended movies randomly. Instead, they chose pictures rated as good or excellent —the criterion being the starring actor or the recommendation of friends. Adults relied little on previews or publicity, which guided the selection of many adolescents.

Data on movie preferences in old age are lacking. Strong's (1931) investigations suggest that the interest in cowboy pictures, which reaches a peak during early adolescence and subsequently declines, is renewed in older men. Educational and travel films become increasingly popular, while the interest in stories based on social problems declines in later years.

Sex Differences in Interests throughout Life Span. So far, we have observed that not only do interests change with age but also that their nature at any age depends on a number of variables, including sex. Such sex differences appear early and persist throughout life. Attempts to appraise sex differences may be illustrated by the research of Terman and Miles (1936), who devised a masculinity-femininity test (M-F test). This test is designed to gauge the extent to which individuals of any age are "typically masculine" or "typically feminine" in interests and attitudes. It consists of roughly 500 items, including word associations; inkblot associations; items dealing with information, opinion, or interest; and emotional and ethical responses.

Changes in M-F scores for both sexes from the eighth grade to the eighth decade are illustrated in Fig. 106. The two sexes diverge considerably by early adolescence. From this time on, males become more and more masculine in their interests, attaining the highest scores, or greatest masculinity, in the eleventh grade. During subsequent years, especially in late maturity, male interests swerve steadily toward the feminine end of the scale. Strangely enough, in our society women's interests also become increasingly masculine until the college years and then shift back toward the feminine end of the scale. The shift is less rapid than for men, however. Because of this differential change, the interests and attitudes of males and females over the age of 60 are more nearly similar than at any other time of life except early childhood. This merging of sex differences was mentioned in an earlier chapter, when it was suggested that it may be related to the relative predominance of estrogens over androgens characteristic of elderly males. We know that the estrogen-androgen balance

shifts with age. Just how or if this shift affects interests and attitudes is as yet a moot question.

Permanence of Interests. As we have noted, increasing age is accompanied by a waning of active in favor of passive pursuits, by a decrease of social in favor of individual interests, and by a growing preference for established routine. Nevertheless, these changes in interests are not so great as might be expected.
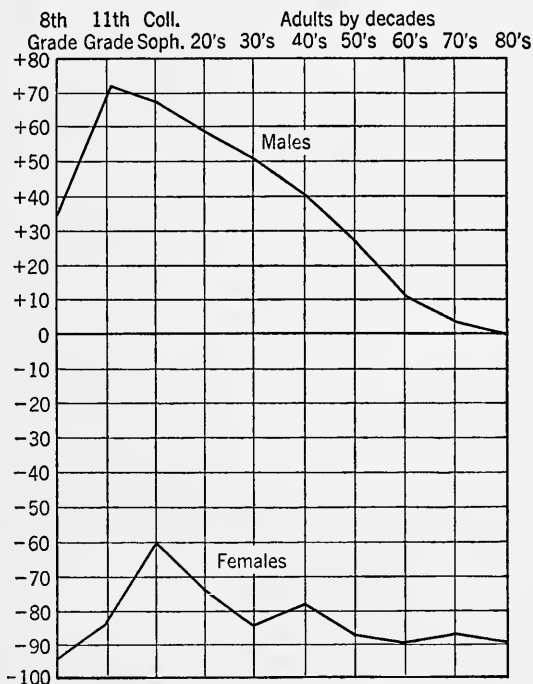
FIG. 106. Age changes in masculinity-femininity interest scores. High plus values indicate the most masculine interests, and high minus values the most feminine interests. Note the increasing femininity of interests on the part of the older males. (*From Terman, L. M., and Miles, C. C. Sex and personality. New York: McGraw-Hill, 1936. P. 123. By permission of the authors and publishers.*)

On a basis of wide research, Strong (1943) reports that the interests of individuals at 25 and 55 years correlate to an extent approximating +.90. Other investigators have reported somewhat smaller correlations. These, too, indicate that adult interests are fairly stable (Thorndike, 1935, for example). The changes which do take place occur relatively early. Assuming that 100 per cent represents the total interest change between 25 and 55 years, we find that 50 per cent occur between 25 and 35, roughly 20 per cent between 35 and 45, and about 30 per cent between 45 and 55. Few

or no changes have been reported for the next decade, 55 to 65. As we might anticipate, the period of greatest change is adolescence. A finer breakdown of this period shows that of the total changes occurring from age 15 to age 25, one-third are found in the single year between 15.5 and 16.5, another third between 16.5 and 18.5, and the last third between 18.5 and 25.

Considering all data together, we see that interests really change very little after adolescence. As Kuhlen (1945) remarks, however, those differences which do exist may be of extreme significance to behavior. Studies invariably stress the importance of channeling interests during childhood. It is difficult to "reform" either vocational or avocational interests in adult years. The man who wants absorbing hobbies in old age must cultivate them during school years.

BELIEFS, VALUES, AND ATTITUDES

In the previous chapter, we discussed the important topic of age changes in interests. Now we shall examine beliefs, values, and attitudes which determine how people feel and think about various social, political, economic, and religious issues. Generally speaking, interests relate to personal likes and dislikes, while beliefs, attitudes and values concern broader issues involving larger social groups. Both attitudes and beliefs are fairly stable. This immediately distinguishes them from opinions, which are frequently short-lived. Both attitudes and beliefs are basic orientations involving perceptual elements as well as learning and intelligence. They originate in infancy and are modified, discarded, and/or supplemented to meet the demands of an increasingly complex environment. They may vary from culture to culture; from one socioeconomic stratum to another; and for different education levels and religious or ethnic groups. On the other hand, some beliefs and attitudes may cut across several societies, for example, the attitude toward war or the belief in God.

Although attitudes and beliefs are similar in many respects, they differ in others. Attitudes are always emotionally toned. They are influenced by our fears, hatreds, loves, and friendships. Thus, our attitude toward Negroes may be influenced by the doctrine of brotherly love (religion); by direct competition on the labor market (economics); by indoctrination pro or con by the home, school, peer group, or propaganda campaign (education); by contact with Negroes (society); by the need to find scapegoats on which to blame our own insecurities; and by many other factors in which we are emotionally involved to varying degrees. Beliefs, on the other hand, may have little or no emotional component. We believe that the world is spherical because factual evidence has been presented; we do not care especially whether it is round or flat or cuboidal.

This differentiation is, of course, extremely broad and settles none of the theoretical controversies common in this field. Here, however, we are interested only in a general picture of development and shall therefore discuss the studies on beliefs, values, and attitudes without attempting to place them in any specific categories.

MEASUREMENT OF BELIEFS AND ATTITUDES

Despite the significance of beliefs and attitudes in determining individual and social behavior, we know almost nothing about them. The major difficulty lies in their complexity, for, as has been pointed out, they involve a great many variables whose relative importance differs from time to time and from individual to individual. Since they are intangibles, they cannot be measured directly. They are reflected in thoughts, actions, and speech and must be appraised indirectly through these avenues. People do not always express their true beliefs in either action or speech, however; they may answer in terms of what they think society or the investigator expects, or they may be quite unconscious of certain attitudes. Thus, no foolproof techniques have so far been devised in this field.

Some Techniques of Measurement. Various techniques have been used to appraise beliefs and attitudes. The most widely known is without doubt the public-opinion poll, in which subjects are asked to answer "yes," "no," or "undecided" to a wide variety of questions. Questions may concern any issue, for example, "Should Negroes be allowed to go to the same theaters as whites?" or, "Should all conscientious objectors be imprisoned?"

Although the opinions of thousands of people may be gauged quickly by this simple method, it is weak in that the yes-no type of answer fails to bring out the strength of the subject's convictions and also fails to permit the subject to qualify or expand his answer, thus frequently presenting a very unreal picture of attitudes on many questions.

To overcome this difficulty, investigators often use a clinical type of interview, in which the subject is questioned at some length and is given opportunity to qualify his responses. The investigator may then ask further questions whenever the original answers are incomplete. Such an interview may be recorded and the material analyzed at leisure. Accordingly, this method gives a broader picture of the individual's attitude toward the subject in question. On the negative side, it is time-consuming and generally requires highly trained interviewers.

Attitude Scales. Attitude scales are almost as popular as public-opinion polls. Such scales are used to appraise attitudes toward such things as war, internationalism, church, religion, and various racial, national, or ethnic groups. A scale consists of a series of statements, usually 20 or 30, all relating to some specific issue such as war. These statements represent varying degrees of favorableness or unfavorableness toward a particular question, the degree depending on the scale value of items. Perhaps this can be made clear by an examination of the first 6 (of 22) items from Dobra's (1930) scale for measuring attitudes toward war:

Scale value	*Item*
0.5	1. Might is right.
2.5	2. When war is declared, we must enlist.
5.2	3. Wars are justifiable only when waged in defence of weaker nations.
6.5	4. The evils of war are only slightly greater than its benefits.
10.6	5. All nations should disarm immediately.
10.7	6. There is no conceivable justification for war.

A subject is required to check all items (randomly presented) with which he agrees. His attitude is then computed as the average of the scale values of all items checked. In the above scale, a low score represents a favorable attitude to war; the higher the score, the more unfavorable the attitude.

Projective Tests. Most attitude studies of the past, especially the public-opinion poll and attitude-scale variety, have been criticized as superficial, failing to get at the deep and often unconscious dynamics of attitudes, for there are many attitudes which people will not reveal in public and many more which are unconscious. It has therefore been suggested that projective tests (see Chapter 15) might be profitably used to appraise attitudes, especially those which cannot be probed by other methods.

Unfortunately, scarcely any work has as yet been done along this line, but what little has been done looks promising. For example, the Thematic Apperception Test was adapted by one investigator to gauge attitudes toward labor (Proshansky, 1943). He selected magazine pictures which illustrated a variety of conflict situations involving labor and which were ambiguous, leaving the outcome of the conflict in doubt. These pictures were shown briefly to the subject, who was requested to make up a story about each situation. A group of judges rated the stories, assessing the degree of pro- or antilabor attitude expressed in each. Ratings were correlated with the scores of the same subject on a standard attitude scale designed to appraise attitude to labor. The high correlation coefficients (from +.67 to +.87) indicated that the picture test successfully differentiated people with regard to pro- or antilabor views. The effectiveness of the technique becomes clear when we examine responses of two subjects to the same pictorial stimulus:

1. Home of a man on relief—shabby—dresses poorly. Scene is probably of a shack down South. Also might be the home of some unemployed laborer. Horrible housing conditions. Why don't the government provide for the people. *The ordinary worker is always forgotten and allowed to rot.*

2. Picture of one room, very messy, stove in center, woman on the left, man standing next to stove, couple of children near them. This is a room of what we call "poor people." *They seem to be messy, sloppy people who seem to enjoy dwelling in their own trash* (italics added).

DEVELOPMENT OF MORAL VALUES

This section concerns the development of morality. By morality we mean a conformity to the standards of conduct set up by a group and considered by them to be the "right" way of acting or thinking. Deviation from this accepted code is considered immoral and is disapproved; if sufficiently extreme, it may incur social ostracism. From such a definition, it becomes apparent immediately that moral standards vary from group to group. There are certain moral values, or "basic virtues," which pervade American culture, however. Among these are fair play, the golden rule, respect for the property of others, loyalty, and honesty. It is in these common standards that we are chiefly interested.

Learning of Morality. The young child is neither moral nor immoral, but nonmoral. He is too young to understand values or to know what is right or wrong. He must learn these before he can act in any moral way. Throughout childhood and adolescence, he gradually learns the accepted codes from parents, teachers, and others in authority. He is rewarded if he does "right" and punished for transgressions. At first his ideas of good and bad are in terms of rules specific to one situation: for example, it is bad to take Bobby's toy. Later he learns to generalize: it is bad to take anyone's toy, and, finally, it is bad to take anyone else's property. Accompanying this growing understanding is a transition from external to internal authority. First, it is bad because mother will punish him if he takes the toy; later, no material threat is needed—he "knows" that it is bad. Thus, gradually, the child assumes responsibility for his own behavior.

Such personal assumption of responsibility is true morality. It is lacking in childhood; it develops slowly and often painfully. When and if it is achieved, however, it is a criterion of social and emotional maturity.

Appearance of Various Moral Values. One of the earliest moral values to appear is the regard for property rights of others. This is present to some degree in the 6-year-old child (Eberhart, 1942). During the next 2 or 3 years, rapid progress is made in realizing the seriousness of stealing. It has been reported that 6-year-old boys can diagnose theft situations almost as easily as the average adult (McGrath, 1923).

Most of the "basic values" of American culture are well inculcated by the eleventh year. Thompson (1949) asked 1,000 children, grades 6 to 12, to list those things for which other boys and girls would praise them. In rank order, the virtues listed as most praiseworthy were honesty, politeness, kindness, cooperation, friendliness, absence of bragging, cleanliness, generosity, and proficiency in social skills. Blameworthy traits included dishonesty, a "bad" character, carelessness, and disloyalty. These moral values were highly esteemed by the grade-6 children. Inter-

estingly, the ratings changed little through the subsequent grades. No sex differences were present. Thus, it appears that regard for the basic virtues has been successfully inculcated by the sixth-grade level and remains stable from then on.

Although certain moral values are achieved early, others continue to develop through adolescence. In one extensive study, children from grade 6 through college were asked to check listed items disapproved of and to
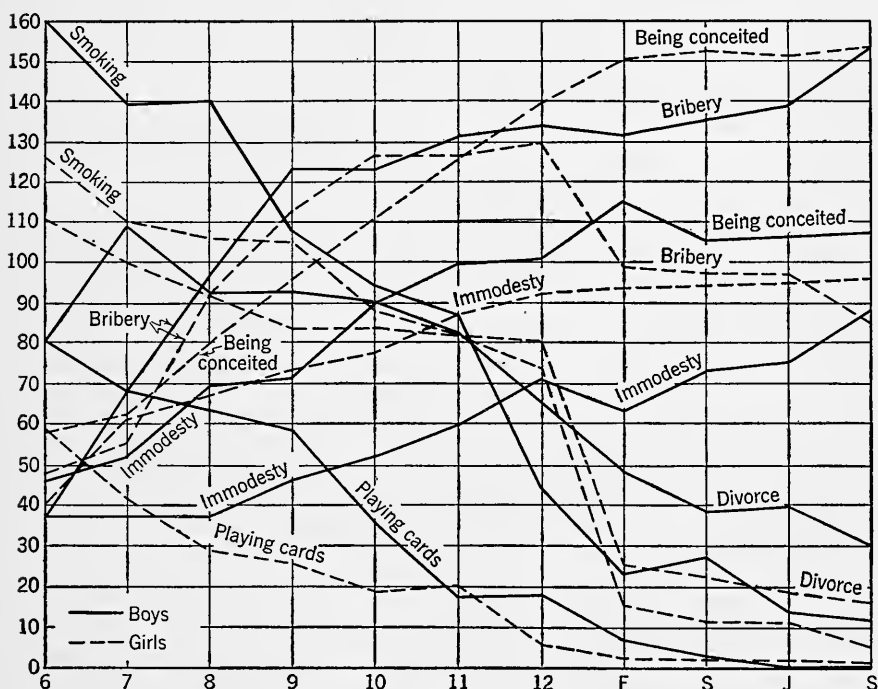
Fig. 107. Age changes in things thought wrong. (*From Pressey, S. L., and Robinson, F. P. Psychology and the new education. New York: Harper, 1944. P. 286. By permission of the publishers.*)

double-check items strongly disapproved (Pressey and Robinson, 1944). The results are illustrated by Fig. 107. Such items as smoking, playing cards, dancing, kissing, and using lipstick were strongly condemned by younger children, but the disapproval diminished rapidly during high-school and especially college years. On the other hand, characteristics such as conceit, predilection for bribery, and immodesty were condemned much more severely by older students than by young children.

Appraisals of Moral Conduct during Later Years. Although studies of age changes in moral values during later life are scarce, those available yield some interesting data.

Perhaps the best investigation was done by Anderson and Dvorak (1928 –1929), who devised a multiple-choice questionnaire of 15 behavior situations dealing with various moral issues. This was given to three age groups —college students, parents, and grandparents. For each behavior situation, four choices of response were possible, dealing with the situation according to (1) a right or wrong standard, (2) a standard set by public opinion, (3) an aesthetic standard, and (4) a standard set by intelligent or prudent judgment. A sample is given below:

If you were at a party where everyone else was drinking, which of the following things would you do: (1) refuse absolutely because you believed it wrong; (2) drink with the crowd; (3) refuse because the action resulting from intoxication would be distasteful to you; (4) refuse because you believed it unwise or unhealthful to drink alcohol?

The most interesting finding was that college students judged the 15 situations according to standards of intelligent judgment and aesthetics rather than by absolute standards of right and wrong. The grandparents, on the other hand, judged according to absolute criteria, and the parents affected a compromise between these two extremes. Public opinion was the least frequent basis of choice at all ages. Age differences exceeded sex differences.

That advancing age is accompanied by an increasing severity in judgments of moral behavior is supported by other studies. For example, Jones (1929) asked teachers of different ages to classify various moral situations as either right or wrong or excusable. The older teachers gave more absolute judgments; the younger teachers favored compromise. There are also indications that older people are much less tolerant of borderline moral transgressions (Cason, 1930).

A *Fortune* survey (1937) revealed that adults over the age of 40 have stricter ideas of right and wrong than do adults under 40 years. The older group, for instance, were less liberal in their views toward relaxing the divorce laws, and more of them objected to premarital sexual intercourse.

RELIGIOUS BELIEFS AND ATTITUDES

Early childhood is probably the most "orthodox" period of an individual's life, in the sense that he accepts his parents' religious teachings unquestioningly—but also without understanding their significance. As he reaches middle childhood, however, the same factors which cause him to challenge other man-made rules also bring skepticism toward certain religious creeds and rituals.

Religious Beliefs during Late Childhood and Adolescence. Using a questionnaire technique, Kuhlen and Arnold (1944) gathered data on the

specific religious beliefs of 12-, 15-, and 18-year-olds. Their results, recorded in Table 32, present a clear picture of the gradual change from almost complete confidence in religious teachings to a compromise between acceptance and rejection.

TABLE 32. CHANGES IN SPECIFIC RELIGIOUS BELIEFS DURING ADOLESCENCE*

Statement	"Believe," per cent			"Not believe," per cent			"Wonder about," per cent		
	12 years	15 years	18 years	12 years	15 years	18 years	12 years	15 years	18 years
God is a strange power working for good, rather than a person.....	46	49	57	31	33	21	20	14	15
God is someone who watches you to see that you behave yourself and who punishes you if you are not good....................	70	49	33	18	37	48	11	13	18
I know there is a God..........	94	80	79	3	5	2	2	14	16
Catholics, Jews, and Protestants are equally good..............	67	79	86	9	9	7	24	11	7
There is a heaven..............	82	78	74	4	5	5	13	16	20
Only good people go to heaven....	72	45	33	15	27	32	13	27	34
Hell is a place where you are punished for your sins on earth.....	70	49	35	16	21	30	13	27	34
Heaven is here on earth..........	12	13	14	69	57	52	18	28	32
People who go to church are better than people who do not go to church.......................	46	26	15	37	53	74	17	21	11
Young people should belong to the same church as their parents...	77	56	43	13	33	46	10	11	11
The main reason for going to church is to worship God......	88	80	79	6	12	15	4	7	6
It is not necessary to go to church to be a Christian..............	42	62	67	38	23	24	18	15	8
Only our soul lives after death....	72	63	61	9	11	6	18	25	31
Good people say prayers regularly	78	57	47	9	29	26	13	13	27
Prayers are answered............	76	69	65	3	5	8	21	25	27
Prayers are a source of help in times of trouble...............	74	80	83	11	8	7	15	10	9
Prayers are to make up for something that you have done that is wrong.....................	47	24	21	35	58	69	18	17	9
Every word in the Bible is true...	79	51	34	6	16	23	15	31	43
It is sinful to doubt the Bible.....	62	42	27	18	31	44	20	26	28

* From Kuhlen, R. G., and Arnold, M. Age differences in religious beliefs and problems during adolescence. *J. genet. Psychol.*, 1944, **65**, 293. Quoted by permission of the Journal Press.

The animistic conception of God as an all-powerful person who watches and punishes the wrongdoer gradually disappears. Seventy-nine per cent of the senior group continue to believe that there is a God, but not all of these regard Him as either benevolent or punitive in character. While only 61 per cent of the older subjects believe in the immortal soul, 74

per cent believe in heaven. This discrepancy may be accounted for by the 14 per cent who believe that heaven is here on earth. Fewer have any clear-cut conception of hell.

Although fairly large percentages continue to believe in God, heaven, and an immortal soul, doubts increase concerning the avenue of approach to either God or heaven. At 12 years, 79 per cent accept every word in the Bible as truth; at 18, only 34 per cent hold to this orthodox view, and only 27 per cent believe that it is sinful to doubt the Bible. The value of prayer is doubted by a greater percentage of the older group. Roughly half as many older subjects consider church attendance of special merit, while more believe that one church is as good as another. Whether this belief that church attendance is not a royal road to salvation is a rationalization for failure to attend or whether attendance drops off because of increasing skepticism regarding its value we do not know. In either event, attendance at church, Sunday school, and other young people's religious organizations drops off sharply during the teens.

Church Attendance. The increasing skepticism toward religious teachings is accompanied by decreased church attendance during adolescence. This is clearly indicated in one study which reports that over 60 per cent of 16-year-olds attend church every week, while less than one-third do so at the age of 24 (Rosander, 1939). This drop may be due in part to the increase of other social activities and to the decline of parental control. Accordingly, it cannot be attributed entirely to increased skepticism.

At this point another variable shows its influence, for church attendance in late adolescence depends on the young person's religion. It has been reported, for example, that 75 per cent of all Catholic youth attend mass every Sunday, while an additional 20 per cent attend frequently. In contrast to this large number, young people of Hebrew faith attend rarely if at all, and only 10 per cent go every week. The average attendance for all denominations is 44.5 per cent. Girls attend more frequently than boys (Bell, 1938).

Discrepancy between Beliefs and Church Attendance. The paradoxical values of adolescents become evident when we consider their beliefs and church attendance in the light of other data. In 1942, a *Fortune* poll requested high-school students to answer the questions, "If you had to give up one of these things, which would you be least willing to give up? Which one would you be most willing to give up?" The attached list included most of the basic freedoms so highly esteemed by democratic citizens, for example, freedom of speech, freedom of religion, the right to vote, and the right to change jobs. The amazing fact emerged that in a country where individual enterprise is the rule and where church attendance is intermittent, to say the least, 59.8 per cent of the teen-agers were willing to surrender the right to earn over $3,000 a year, and 20.8 per cent were willing

to give up the right to change jobs at will, but only 1.8 per cent were willing to sacrifice religion. Only freedom of speech preceded freedom of religion in their hierarchy of values.

Although we have no data on adults, we might venture to guess that a corresponding situation exists. Seemingly in our society we pay lip service to the right to worship as we choose but refrain from expressing this publicly, at least, through church attendance.

Religious Problems of Adolescents. From the above discussion, it appears that sooner or later most adolescents have religious problems. This is unavoidable, for, as youngsters mature intellectually, they begin to note the inconsistencies between theory and practice. Kuhlen and Arnold (1944) list the most frequent problems of the teen-ager. They concern sin, heaven and hell, the real meaning of religion, the conflicts between science and religion, what happens after death, and guilt over disliking church services. These problems become more acute in later adolescence.

Religious Beliefs during College Years. We often hear that college students, especially science students, show marked changes in religious outlook. Although changes do occur, they are less pronounced than is popularly believed.

The most extensive investigation of the beliefs of college students was conducted at the University of Syracuse (Katz and Allport, 1931). According to data assembled, 53 per cent of those students who believed in a "personal God" before college continued to do so after graduation, while 28 per cent had shifted to a view of God as an "Intelligent Being." Of those who regarded God as an "Intelligent Being" on entering college, about 80 per cent did so after graduation. Thus, the changes were neither frequent nor extreme. It is interesting, too, to note that only two students became atheists during college years; of the three who were atheists at the time of enrollment, all abandoned the view. The popular notion that colleges are breeding grounds of atheism therefore appears to be without foundation. What does happen is that the student tends to become more critical of religious teachings and more liberal in his views of religion.

Causes of Changing Religious Beliefs. Those University of Syracuse students who reported changed religious views during college years gave various reasons for the alteration. According to Katz and Allport, the alleged causes were (1) influence of the teachings of certain courses, checked by 72 per cent of this group; (2) contact with fellow students, checked by 46 per cent; (3) the general process of maturing, checked by 30 per cent; (4) personal influence of professors in courses, checked by 21 per cent; and (5) other influences outside college, checked by 20 per cent. Miscellaneous items contributed in only a small minority of cases.

Changes in Reasons Given for Attending Church. Alleged reasons for attending church change markedly during the life span. Some of these age

changes are illustrated in Fig. 108. During the first 25 years, the young person considers church as an aid in formulating a "philosophy of life" and as a place to make friends and to hear good literature and music. As he grows older, these motives diminish in importance, to be replaced by the desire "to keep alive the spirit of Christ," to receive assurance about immortality, and to encourage family attendance. Most interesting of these changes is the concern over immortality. This is high during youth, then seems to lie dormant between the ages of 25 and 50—perhaps due to
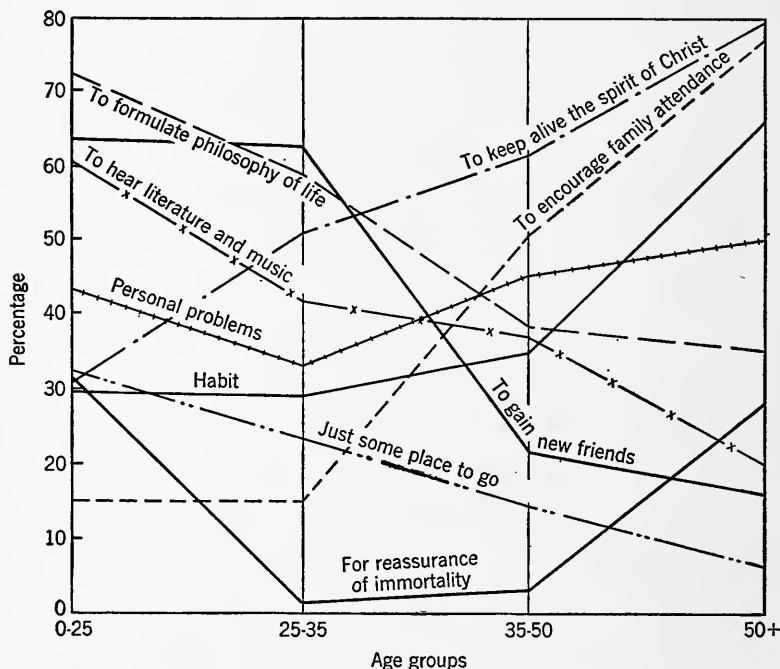
FIG. 108. Age changes in reasons for attending church. (*After Kingsbury. From Pressey, S. L., Janney, J. E., and Kuhlen, R. G. Life: a psychological survey. New York: Harper, 1939. P. 429. By permission of the publishers.*)

preoccupation with socioeconomic affairs—and comes strongly to the fore again in late maturity.

Religious Beliefs in Old Age. What are the religious beliefs of our senior citizens as they approach the end of life? There are only two good studies bearing on this question.

Over 50 years ago, Starbuck (1900) reported that elderly people were greatly concerned with the question of immortality. Some definitely accepted it; others rejected the belief entirely. Other religious convictions which become stronger with the years is the belief in God, the belief that

religion is "a life within," and feelings of reverence for and dependence on God. Such age increases are most conspicuous in women.

Half a century later, Cavan *et al.* (1949), using an interview and mailed-questionnaire technique, obtained data on the religious beliefs of 499 males and 759 females ranging in age from 60 to 100 years. The sample, scattered throughout the United States, included all major religious denominations. The age changes in religious beliefs and activities of both males and females are recorded in Table 33.

TABLE 33. RELIGIOUS ATTITUDES AND ACTIVITIES DURING THE LATER YEARS*

Attitude or activity	Percentage of age group with given religious attitude							
	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–99
Males								
Favorable attitudes toward religion	38	41	42	39	53	55	50	
Certain of an afterlife	71	64	69	67	72	81	100	100
Attend religious services once a week or oftener	45	41	46	45	50	45	17	
Listen to church services regularly on radio	16	21	19	26	33	37	20	50
Read Bible at least once a week	25	29	33	41	48	45	33	25
Females								
Favorable attitudes toward religion	51	56	57	64	69	81	93	100
Certain of an afterlife	83	78	86	77	91	90	100	100
Attend religious services once a week or oftener	60	53	52	53	56	33	50	
Listen to church services regularly on radio	22	27	37	30	46	59	69	100
Read Bible at least once a week	50	60	64	62	61	76	58	100

* From Cavan, R. S., Burgess, E. W., Havighurst, R. J., and Goldhamer, H. *Personal adjustment in old age.* Chicago: Science Research Associates, 1949. P. 58. By permission of the publishers.

Study of Table 33 indicates that a favorable attitude toward religion increases over the age span studied, the increase being more pronounced in women. Belief in an afterlife is held by the majority of 60-year-olds and by 100 per cent at age 90. Listening to church services over the radio also increases with age, while attending church and reading the Bible weekly increase to age 80, declining somewhat thereafter. This drop is not due to flagging interest, however, but to impairment of physical powers which limits both locomotion and amount of reading. The over-all picture is one of growing preoccupation with religion as the individual ages and of

an increase in the feelings of security afforded by religion, especially among women.

Summary. From an over-all perspective of religious development throughout the entire life span, we may summarize as follows: The young child uncritically accepts the faith of his parents. He turns away from it relatively early, becoming involved in the conflicts which inevitably result from the paradoxical values of our society. Doubt and confusion may last for many years and appear even in old age, as evidenced by the great concern over immortality. Apart from this concern, the later years are characterized by a return to former beliefs and by increasing comfort derived from religion.

SOCIAL-ECONOMIC-POLITICAL BELIEFS AND ATTITUDES

So far, we have discussed the development of moral and religious beliefs and attitudes. As we come to attitudes of a social, economic, and political nature, we find little material relevant to attitude development. Most of the literature in this area deals with the development of a competitive attitude, the urge to succeed, and prejudices toward various racial, national, and ethnic groups. Let us examine the studies briefly.

Development of Competitiveness. In a formal sense, children have no political or economic views. Indoctrination begins early, however.

Perhaps the essential feature of our democracy is the competitive spirit, characterized at adult level as a free-enterprise philosophy. This is fostered in children by the home, school, and other agencies. Its growth is clearly shown in Greenberg's (1932) study of children aged 2 to 7 years. These children from varied home backgrounds were brought into a small room, two at a time, and asked to build something with the blocks on the table. When this had been done, they were asked which of the two things built was the prettier. Next, this instruction was given: "Would you like to see who can build prettier?" Following this, a third task was assigned: "Now let me see who can build bigger." Detailed protocols were made of all the children's comments, gestures, and activities and the general mood of the building situation.

Analysis yielded the data recorded in Table 34. No competition in the construction of objects appeared in children under 3 years of age. By age 6, however, almost 90 per cent showed it in well-developed form. Greenberg observed that this growth of competitiveness passes through four well-defined and orderly stages: (1) no competition—interested primarily in manipulating the blocks (2 to 3 years); (2) slight degree of competition—discovers the other child but is more interested in the social relationship than in excelling (3 to 4 years); (3) competition—becomes conscious of blocks as material for work, understands the problem, and

TABLE 34. PERCENTAGE OF CHILDREN OF DIFFERENT AGES SHOWING COMPETITION*

Age	Present	Absent	Doubtful
2–3	0.0	89.5	10.5
3–4	42.6	55.6	1.8
4–5	69.2	23.1	7.7
5–6	75.4	15.8	8.8
6–7	86.5	5.4	8.1

* From Greenberg, Pearl J. Competition in children: an experimental study. *Amer. J. Psychol.*, 1932, **44**, 239. Quoted by permission.

shows desire to excel (4 to 6 years); (4) competition—desire to excel is much stronger and begins to show critical judgment of the product (6 to 7 years). Thus it appears that by the time the average child starts school his competitive attitude is well developed.

Competition as Incentive. That competition is an effective incentive with children as young as 5 years was demonstrated by Wolf (1938). Her 5-year-old subjects were tested in three situations. In the first situation, no incentive was offered other than the child's interest in the activity. The median time spent at the activity was between 3 and 4 min. In the second situation, a familiar person praised the child's performance. In response to such reward, the median time increased to between 6 and 7 min. Finally, in the third situation, each child competed with three classmates. Competition lengthened the activity period to between 11 and 12 min.—almost doubling the time spent in response to praise, and tripling the time spent with no incentive. Wolf points out, however, that praise might have been more effective had it been given by someone the child loved—his kindergarten teacher or his mother, for instance. Competition at this age (and possibly later) gains or losses in effectiveness depending on the interpersonal relations of the competitors.

Numerous investigators have studied the effects of praise and competition or rivalry in school learning situations. All point to improved performance. This is not surprising, for competition is the basis of school grades; of attaining honors in either academic work or voluntary school societies; and of taking part in school plays, ball games, debates, and almost every extracurricular activity. To excel is to succeed, and success means reward both in school and at home.

Urge to Succeed. A number of investigators have tried to find out at what time of life the urge to succeed or to get ahead is at a maximum. Kuhlen (1952b) reported that teachers evidenced the greatest urge to succeed during the middle and late 20's; after the age of 30, the desire declined rapidly. The maximum drive occurs somewhat later for some other vocations, however. According to Lehman and his associates (1943, 1949),

people write most books, publish most articles, and make most discoveries while in their 30's; these achievements reflecting personal ambition and initiative decrease rapidly after the fourth and fifth decades.

The age changes in the desire to succeed are clearly evident in one study which analyzed the reasons why people enrolled in extension courses (Smith, 1935). Between the ages of 15 and 35, subjects registered in the hope of advancing themselves in their respective occupations; from 40 to 59, some continued to study for the sake of advancement, but others chose nonvocational courses; beyond the age of 60, scarcely anyone enrolled for vocational reasons. Thus it seems that the strongest urge to succeed comes relatively early in life, the approximate age depending on the nature of the occupation. After middle age, success in most fields and to most individuals becomes less and less important.

Age Changes in Political-Social-Economic Attitudes. Studies of age differences in attitudes toward various social-political-economic issues are numerous but, unfortunately, contradictory. It has been reported, for example, that younger and older adults show similar attitudes to social issues (Sullivan, 1940) and exhibit no differences in liberality of view (Gundlach, 1939), in degree of international-mindedness (Young, 1929), or with respect to conservatism-liberalism (Harper, 1927).

On the other hand, several analogous studies report age differences in social-political attitudes. In support of this view, we have the finding that parents are more conservative than their children and that older parents are more conservative than younger parents in their attitudes toward Communism and the Church (Newcomb and Svehla, 1937–1938). Another investigator states that parents are less pacifistic than their daughters and favor capital punishment more than their daughters (Duffy, 1941). We might, perhaps, conclude that elderly people are not much more conservative in their views than their younger contemporaries but that the degree of difference relates to the particular issues under study.

Attempts to Change Attitudes. It is generally believed that the attitudes of older people have crystallized and hence are difficult to change. Such experimental evidence as we have supports this belief.

Marple (1933) reports an interesting study on a deliberate attempt to change attitudes. His three groups of subjects included 300 high-school students with a mean age of 18 years, 300 college students whose mean age was 22, and 300 adults with a mean age of 39 years. All subjects were given a preliminary questionnaire containing 75 controversial problems or situations such as the following:

    a. Real estate owned by religious organizations should be subject to taxation.

    b. The installment plan of buying has done more harm than good to the stability of American economic life.

After this initial test, each age group was subdivided into three parts. The first third of each group was retested after a month without any intervening attempt to change their beliefs, the second third was informed of majority opinion on the initial test prior to the retest, and the last third of each age group was told the opinion of experts on each question involved. Analysis indicated that high-school students changed more than college students who in turn changed more than adults. All shifts were in the direction of majority opinion rather than expert opinion. This finding is entirely in line with our earlier comments that the need for conformity is greater in adolescence than at any subsequent age. Accordingly, deliberate attempts to change beliefs are more successful among the younger subjects. It might be added that this study appears to measure opinions rather than attitudes.

Development of Ethnic Prejudice. Prejudices are judgments made prior or contrary to fact. If education, experience, and intelligence accomplished what we often expect them to achieve, we might anticipate that advancing age alone would eliminate prejudice and that such false attitudes would decrease in inverse ratio to education or intelligence. Logically, this may be so; factually, it is untrue. Attitudes are highly emotionally toned, and, as we know, emotions are no respecters of reason. Prejudices may undermine any logic. A few studies will be discussed which illustrate the development of racial or ethnic prejudice.

Appearance of Prejudice. It is a common observation that young children show no racial discrimination but that by adulthood prejudice may be quite pronounced. The absence of racial discrimination among young children has been demonstrated by various investigators. In one study, individual photographs of Negro and white children were shown in pairs to kindergarten and first-grade children who were asked to select the picture that they liked the best. At this age, subjects apparently did not notice that some of the pictures were of colored children and selected the two races equally often. Similar choices were made by Negro children. It was not until the fifth grade that any marked degree of prejudice was noted (Moreno, 1934). However, other investigators claim that incipient prejudice against Negroes is found as early as kindergarten (Horowitz, 1936). We might conclude, then, that prejudice begins fairly early in the life of the average child.

In the study cited above, Horowitz questioned rural Tennessee children regarding the origin of their prejudices, asking questions like, "Who tells you what you should do?" "What kind of children does she [the mother] like you to play with?" "What kind of children does she tell you not to play with?" The following responses are typical:

First-grade girl: "Mamma tells me not to play with black children, keep away from them. Mamma tells me, she told me not to play with them. . . . "

Second-grade girl: "Colored children. Mother doesn't want me to play with colored children. . . . I play with colored children sometimes and mamma whips me."

Second-grade boy: "Colored children, mother and daddy tell me. They tell me not to play with colored people or colored persons' things."

Third-grade girl: "Mother told me not to play with them because sometimes they have diseases and germs and you get it from them" [quoted from Krech and Crutchfield, 1948, p. 180].

Even a casual examination of these responses reveals the following learning sequence: (1) Don't play with colored children (or children from other racial or ethnic groups) or you will be punished; (2) don't play with anything that belongs to them; and (3) don't play with them because they have diseases. Thus the child gradually learns that a stigma is attached to colored people (or other ethnic groups) and learns to associate undesirable characteristics with them.

It is easier to teach these lessons when differences are conspicuous, as in the case of color, but the child learns to discriminate between the "socially desirable" and "socially undesirable" socioeconomic strata in the same way. It takes a while for these lessons to become effective. During the gang age of middle childhood, membership is still not determined by either color or status. The adolescent cliques and crowds, however, discriminate according to both color and status criteria. Sometime during the transition period they have learned the lesson only too well. Parents, who fear marriages with undesirables, enforce segregation even more strictly on the teen-ager.

Prejudice at High-school Age. Zubek (1952) followed the development of prejudices through the high-school years to adulthood. Using a Thurstone type of attitude scale, he studied the attitudes of Canadian adolescents and adults toward an ethnic group, the Doukhobors, who lived in the immediate vicinity of the schools where the tests were given. The Doukhobors are not colored; they are a religious sect of Russian origin who practice communal living as opposed to the free-enterprise system of their neighbors and of Canadians at large. Considerable adverse publicity has been given the group because of the practice of a small segment of their number, known as Sons of Freedom, of using nudism and incendiarism as protest devices against government regulations.

Zubek found that the amount of prejudice increased significantly from the ninth through the twelfth grades. A group of adults, who were also tested, did not differ significantly from the grade-12 students but tended to give more neutral responses. On the whole, the Doukhobors were known for their unfavorable rather than favorable characteristics. These unfavorable qualities were based on generalizing from the antisocial Sons of Freedom to all Doukhobors. Interestingly, though, 41.5 per cent stated

that they disliked the sectarians because "they refused to obey Canadian laws," and 32.3 per cent disliked them because they were "dishonest," while only 15.4 per cent gave as a reason the more conspicuous and better publicized characteristic of protest stripping.

Prejudices of Adults. The 98 adult responses in Zubek's study were further analyzed according to occupation—competitive vs. noncompetitive. As we might anticipate, the competitive group showed greater hostility toward their Doukhobor neighbors than did the noncompetitive to whom the prosperous and industrious sectarians offered no threat in the labor market. Since age, education level, etc., were not controlled in this study, the importance of competition as compared with other variables cannot be estimated.

The relative contribution of several variables to adult ethnic prejudices is shown more clearly as a by-product of a study by Solberg (1953). A story technique was used to measure (among other things) attitudes toward such ethnic groups as the West Coast Japanese and the French Canadians. Attitudes toward both groups reflected competitive influences, but every story of the battery served to corroborate the importance of the "wealth-prestige" motif among urban Canadians. At all adult age levels, economic influences exceeded the effects of either age or education. Thus our values appear to be more like those of our fellow workers than like those of our own age group.

Findings of other investigators corroborate the economic influence on prejudices. To date we have no well-controlled studies in which age trends can be isolated from other variables.

CHAPTER 15

PERSONALITY

We have now reached the most difficult of all aspects of the study of human development—personality. Psychologists fail to agree on either definition or legitimate research techniques. For present purposes, however, we may think of personality as the "concept under which we subsume the individual's characteristic ideational, emotional and motor reactions and the characteristic organization of these responses" (Katz and Schanck, 1938). In this definition, the important word is "characteristic," for instance, ideas, feelings, and actions peculiar to an individual and therefore differentiating him from others of his kind. Such distinguishing features constitute personality. Like other aspects of development, personality is neither exclusively biological nor exclusively social but depends on the interplay between naturally endowed factors and social experiences.

METHODS OF APPRAISING PERSONALITY

Since personality is not a single entity but a complex of many reactions, it cannot be measured by a single test. Accordingly, we are forced to appraise various aspects—sociability, aggressiveness, introversion-extroversion, confidence, self-reliance, and so on—separately. Such separate and definable parts are often referred to as personality *traits*. Through the use of various tests, each measuring one or another facet, some sort of picture of personality as a whole may be achieved. In a given instance, however, the appraisal technique selected depends largely on what facet we wish to study. To learn something about the aspect designated as temperament, for example, we choose tests which reveal the individual's susceptibility to various emotional stimuli; gauge the speed with which emotions are aroused; determine the intensity, quality, and frequency of change in emotional reactions; etc. To determine characteristic likes and dislikes we might use a questionnaire such as the Strong Vocational Interest Blank. Although appraisal techniques are numerous, we shall mention only a few.

Case History. The case history is by far the most comprehensive method of studying the individual's characteristic response patterns. The

subject is often interviewed at some length. He is given tests of various kinds, including appraisals of intelligence, aptitudes, interests, and attitudes. His medical history is checked. Parents, teachers, employers, and others may add pertinent data, and biographical materials such as diaries and letters may contribute. Combining data from all available sources, the investigator builds a composite picture of the subject's personality. Case histories are used most frequently by clinicians and social workers for practical purposes such as guiding officials in committing persons to various institutions and in subsequent release of patients.

Miniature-life-situations Tests. Doubtless the ideal method of studying personality would be through direct observation of a subject's behavior in specific social situations. Perhaps this method is best exemplified in Hartshorne and May's (1929) work. Grade-school children were placed in situations affording opportunities for self-sacrifice, cheating, stealing, etc. In one particular test situation, subjects were required to solve intricate puzzles in an insufficient period of time. Dishonest solution was possible if some pieces of the puzzle were lifted off the board. At the end of the period, the children were asked if they had cheated. Although this is an excellent method, it is time-consuming and shares a disadvantage common to all direct techniques in that it can be used to study only certain personality traits.

Paper-and-pencil Life Situations. Although actual life situations may be difficult to stage, they can be duplicated to a certain extent either verbally or on paper. A specific social situation may be described to the subject who is then asked how he would react to it. The following item, abstracted from Allport's ascendance-submission test, provides a good example:

At church, a lecture or an entertainment, if you arrive after the program has commenced and find that there are people standing but also that there are front seats available which might be secured without "piggishness" or discourtesy but with considerable conspicuousness, do you take the seats?

> habitually   ....
> occasionally   ....
> never   ....

This method has the advantage of exploring a wide range of behavior, especially of the kind that would be difficult to sample in an actual life situation. However, it has the serious disadvantage that the answers may not be truthful.

Questionnaire or Inventory. A much simpler technique consists of merely giving the subject a series of questions or statements each of which he is required to answer by circling the "yes," "?" or "no" after it. Ques-

tions may concern emotions, attitudes, or a variety of behavioral items. An example from Guilford's (1940) Inventory of Factors STDCR, comprised of 175 such questions, illustrates this type:

S	Are you inclined to limit your acquaintances to a select few?	YES ? NO
T	Are you inclined to analyze the motives of others?	YES ? NO
D	Are you sometimes so "blue" that life seems hardly worth living?	YES ? NO
C	Do you have frequent ups and downs in mood, either with or without apparent cause?	YES ? NO
R	Are you inclined to act on the spur of the moment without thinking things over?	YES ? NO

Scores are assigned for each of five factors. A high total score for *S* items indicates that the subject is shy and seclusive; for *T*, that he is inclined to meditative thinking; for *D*, that he is characteristically pessimistic or gloomy in mood; for *C*, that he has strong emotional fluctuations; and for *R*, that he has a carefree disposition.

The inventory type of test has been especially useful in studying such characteristics as introversion, self-sufficiency, and neurotic tendencies as well as interests, attitudes, and values. One of its major limitations is its high dependence on the subject's honesty.

Rating Scales. Rating scales have been popularized in magazines and newspapers and are thus familiar to everyone. They may be used by the individual, to appraise some specific trait, or by friends or associates. Such scales generally contain descriptive adjectives indicating various degrees of a trait. If we wish to determine a subject's boldness or shyness in social situations, for example, we might ask his friends to select the appropriate descriptive phrase from the following scale:

Painfully self-conscious	Timid, frequently embarrassed	Self-conscious on occasions	Confident in self	Bold, insensitive to social feelings

In general, rating scales are unreliable. They are not a good method of appraising personality if used without supporting data. Nevertheless, they are frequently used, especially in industry.

Projective Techniques. In recent years, projective techniques have become extremely popular for appraising certain aspects of personality. Not only do they differ in administration from the tests discussed earlier, but they also place greater emphasis on motivational and patterning aspects. The basic underlying premise is selective perception; people see what they want to see and think what they want to think. In the falling raindrop, for example, the poet "sees" beauty, the small boy sees a puddle for sailing

a boat, the farmer sees a bountiful harvest, and the housewife sees mud on her freshly scrubbed floor. The major problem is not to obtain differential views of the raindrop but to interpret what these views mean.

Falling rain or cloud formations would provide excellent material for tests if they were sufficiently permanent for repeated use. Since they are not, other ambiguous stimuli have been devised. Most common is the Rorschach, or ink-blot, test; another frequently used is the Thematic Apperception Test, more often known as the TAT. Both of these require the subject to tell about various ambiguous pictures.

The Rorschach Test. Many clinicians consider the Rorschach test the most effective tool so far devised to appraise personality. It consists of a set of cards, each containing an ink blot. The cards are presented individually to the subject, who is merely asked to tell what each looks like. Responses are recorded and interpreted in terms of a number of criteria: Does the subject see what others see? How does he approach the problem? Does he organize the content into meaningful wholes or does he interpret in terms of details of a picture? Does he respond to outline? Does he express action, or are the forms seen as static? Does he respond to color in the few colored cards? On the basis of such analyses the tester is able to tell something about emotional desires, attitudes, conflicts, etc.

The Thematic Apperception Test. In the TAT, a series of pictures are also shown separately, and the subject is asked to tell what is happening in the pictorial situation, to reconstruct what has gone before, and to indicate what will follow. Stories will reflect the subject's own experiences and will be colored by his emotional reactions to hypothetical situations. Scoring on this, as on the Rorschach, has been standardized but is, nevertheless, intuitive to a degree. Results of interpretations are similar to those of the Rorschach.

Other Appraisal Techniques. There are many other methods of appraising personality. Although psychoanalysis is widely used, it is far too comprehensive to be explained in limited space, for interpretation is based on a complex system of underlying theory. It draws on case history, psychiatric interviews in which the subject recalls and verbalizes events from his past, free-association tests, dream analysis, and other sources.

Appraisals of personality have also been attempted through analysis of drawings, sculpture, and other forms of creative art as well as through play.

Psychograph. It has already been observed that any appraisal of personality is based on several tests, each sampling one or more facets. Some method is therefore needed to assemble the scattered data into a composite picture of the total personality. To some degree this can be achieved by the *psychograph.* The psychograph is simply a chart on which the various measurements obtained are plotted in graphical form. Scores on the

several tests are usually translated into percentiles, enabling a person's position to be indicated with reference to the rest of the population.

Figure 109 shows the psychograph of subject E.Y. According to this record, he is an individual of inferior intellectual ability, extremely neurotic, highly introverted, and very submissive.
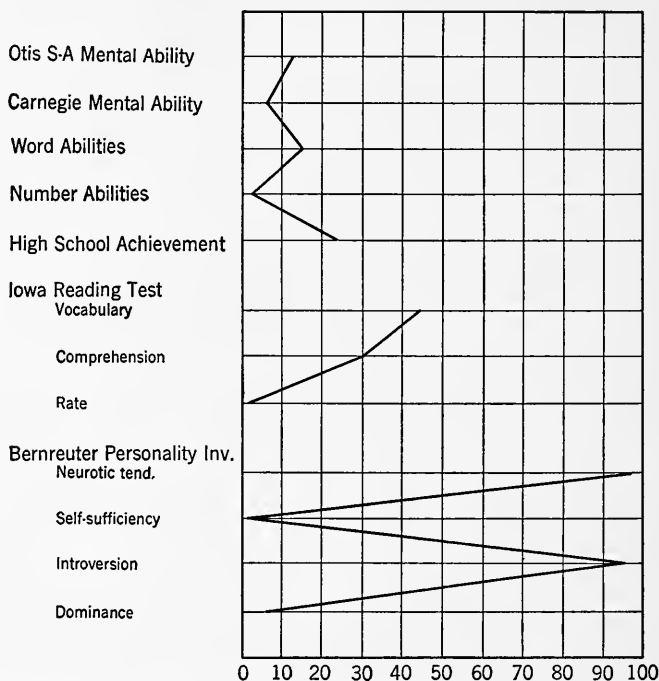
FIG. 109. Psychograph of subject E.Y. in percentile units. (*From Shaffer, L. Psychology of adjustment. Boston: Houghton Mifflin, 1936. P. 455. By permission of the publishers.*)

SOME FACTORS INFLUENCING PERSONALITY

Personality is exceedingly complex. Of the many biological and social factors which influence it, only a few of the more important will be mentioned.

Glandular Factors. Disturbances of the endocrine system of the body—especially if pronounced—may influence the responses and reaction patterns of the individual. This applies particularly to temperament and general vigor. Perhaps the clearest illustration is thyroid malfunction. Underactivity of the thyroid slows down metabolic processes and results in sluggishness and lethargy, frequently accompanied by states of depression. Hyperactivity of this gland may produce nervousness, excitability, restlessness, and general overactivity. Again, a disturbance of the adrenal

cortex may lead to an increase in masculinity, especially in women. As was observed earlier, some of the personality changes that occur around puberty are associated with maturation of the sex glands.

Morphological (Anatomical) Factors. Structural characteristics such as height, weight, body proportions, and physical attractiveness may influence the development of personality traits. Children are highly critical of deviants who may be "too" tall or short, thin or fat. Such deviants are often regarded unfavorably and excluded from the social group. As a result they may develop feelings of inferiority, become shy and retiring, or otherwise compensate. The operation of the physical factor may be seen most clearly in cases of actual deformity. It is an established fact that fewer physically handicapped children than well-formed youngsters develop normal personalities. In one study, for example, the Thurstone Personality Schedule was used to test two groups of children of the same age, one comprised of normal subjects and the other of cripples. Test scores of the physically handicapped children placed them in the category of the emotionally maladjusted (Rosenbaum, 1937).

Parental Influence. According to Shirley (1941) and others, the personalities and attitudes of the parents contribute more to the development of a child's personality than any other environmental influence. This is logical, for parents' personalities permeate their every action and thus determine care and discipline as well as the socioemotional atmosphere of the home. This point is emphasized by Symonds (1938):

> The child who is wanted by his parents and grows up in a home atmosphere that is characterized by understanding, loving care and affection, has every chance to develop into a well-balanced, emotionally stable adult. The child who is neglected or brutally treated by either parent, or even the child who is rejected in more subtle ways—by criticism, hostility submerged under a cloak of insincere care and affection—is destined on the average to show aggressive traits, to be hostile and antagonistic toward those with whom he must have dealings and to develop tendencies which may lead to delinquency [p. 486].

Birth Order. It is quite commonly believed that the personality of a first-born child differs considerably from that of middle or last-born children. Certain psychoanalysts especially have fostered this view. Adler (1930), for example, maintained that a child's personality structure is definitely related to his ordinal position in the family and stressed the differential environments resulting from birth order. Innumerable studies have been carried out to determine the relative merits of various ordinal positions, but the results have been contradictory (see review in Hurlock, 1950).

It seems likely that the effect which ordinal position will have on personality depends on the characteristics of the child himself and on how the

parents react to the changing family structure. The question is well summarized by Munn (1938):

> The whole problem of birth order is merely a potential one. Whether or not a given birth order shall have given effects depends upon such factors as age differences, the personality of the child when the new situation arises, the way in which the parents react to the situation, the reactions of other children (if more than two siblings are involved), the presence of other adults in the home, the socio-economic status of the family, how much attention the children normally receive from the parents (they may be attended to primarily by maids) . . . and so on.

> What we have said about birth order is, in general, also true of the "onliness" problem. Widespread opinion has it that "only" children are always problem cases. One hears it said that they are spoiled, selfish, neurotic, sissy and so forth. . . . Statistical investigations and case studies do not support such a generalization [p. 500].

Effect of Cultural Patterns. The importance of cultural influences on personality development is shown clearly in the extensive work of Margaret Mead (1937). Mead observed that among the Arapesh of New Guinea the prevailing characteristics of both sexes are gentleness, cooperativeness, and unaggressiveness. On the other hand, the Mundugumors, who live only a few miles from the Arapesh, are known for their competitiveness, aggressiveness, and hostility. The Zuñi Indians of New Mexico are noted for cooperativeness, selflessness, and lack of self-assertion. In contrast to the Zuñi, the Kwakiutl Indians of British Columbia have competitive characteristics perhaps more highly developed than in any other society. These few examples indicate that many personality characteristics may be culturally determined.

EMERGENCE OF PERSONALITY CHARACTERISTICS

Most investigators who have studied the personality of infants agree that very early in life differential response patterns emerge which distinguish them as individuals, distinct from other infants, and that these characteristics tend to persist.

The early appearance and persistence of personality characteristics in infants were demonstrated by Shirley (1933b). She studied 22 infants within 24 hr. of birth and followed their progress for the next 2 years, recording temperament and social characteristics. Many of the children exhibited differential responses within the first 2 weeks and retained these distinguishing features throughout the period studied. Virginia Ruth, for instance, was the most irritable of the babies during the first 2 weeks and remained most irritable; Judy was initially most vocal and continued to be so. Shirley concluded that "traits are constant enough to make it

plausible that a nucleus of personality exists at birth and that this nucleus persists and grows and determines to a certain degree the relative importance of the various traits. Some change is doubtless wrought by environmental factors, but this change is limited by the limitations of the original personality nucleus."

Although Shirley's data indicate that infants can make certain characteristic reactions within the first 2 weeks, other investigators claim that this occurs later. However, the consensus of findings places appearance of such distinguishing features well within the first 4 months of life.

PERSISTENCE OF PERSONALITY CHARACTERISTICS

Whether or not behavior patterns remain constant from year to year as growth proceeds is obviously important to home training, school, and clinic. Accordingly, many attempts have been made to explore this problem, both in early childhood and in later life. We shall consider these studies by age groups.

Preschool Period. Perhaps the best study of the persistence of traits in young children was done by Gesell and Ames (1937). Movies were made of the same subjects at ages 1 and 5. A trained observer who did not know any of the children was then asked to rank the pictures according to 15 traits such as energy output, social responsiveness, sense of humor, and emotional expressiveness. The correspondence between the traits appraised at the two ages for five children is summarized in Fig. 110. Without doubt the most striking feature is the amazingly high correspondence. Of 75 judgments (five children ranked on 15 traits each), 48 coincided, 21 showed discrepancies of only 1 rank order, 5 were displaced by 2 ranks, and 1 was displaced by 3 rank orders. Least stable of the 15 traits were communicativeness and reaction to success. The investigators state that "our periodic cinema records clearly show prophetic characters in behavior traits in the first year."

Research in this area was prolific during the 1920's and 1930's. Several of the studies are summarized in Table 35. It can be seen that such characteristics as aggressiveness, perseverance, smiling, sociability, laughing, and crying all tend to persist throughout the preschool years.

Childhood and Adolescence. The investigations mentioned so far cover relatively short time intervals. Longitudinal studies appraising behavior intermittently over longer periods are much more valuable. To date, however, we have only one such study. Shirley (1933*b*) began this investigation when she contributed sketches of 25 infants in the first 2 years of life. About 15 years later, Neilon (1948) made a follow-up of 15 of the original "Shirley's babies," who were at that time around 17 years old. Without having read the earlier descriptive materials, Neilon prepared

a set of sketches of the 15 adolescents. Matching the infant and adolescent sketches became the task of 10 judges not otherwise involved in the study. Matchings were better for some children than for others—for example, several sketches were matched by 10 out of 10 judges; others, by fewer or

Rank order profiles

o At one year of age
• At five years of age
● At both ages

Behavior traits	Boy D 1 2 3 4 5	Boy A 1 2 3 4 5	Girl A 1 2 3 4 5	Girl B 1 2 3 4 5	Boy B 1 2 3 4 5
1 Energy output					
2 Motor demeanor					
3 Self dependence					
4 Social responsiveness					
5 Family attachment					
6 Communicativeness					
7 Adaptivity					
8 Exploitation of environment					
9 Humor sense					
10 Emotional maladjustment					
11 Emotional expressiveness					
12 Reaction to success					
13 Reaction to restriction					
14 Readiness of smiling					
15 Readiness of crying					

Summary: Total No. of rank orders   75
No. of correspondences   48
No. of displacements, 1 order   21
No. of displacements, 2 orders   5
No. of displacements, 3 orders   1

FIG. 110. Correspondence between the appraisal of traits at 1 year of age and at 5 years. (*From Gesell, A., and Ames, L. B. Early evidence of individuality. Sci. Mon., N. Y., 1937, **45**, 219. By permission of the American Association for the Advancement of Science.*)

none. There was definite evidence, however, that many of the personality characteristics had persisted over the 15-year period. Some adolescents could be readily identified by the infant sketches—possibly because of the greater uniqueness of personality patterning.

Adulthood and Later Years. Not only do some personality characteristics persist through childhood and adolescence, but many also remain rela-

TABLE 35. STUDIES OF PERSISTENCE OF PERSONALITY TRAITS IN PRESCHOOL
CHILDREN

Investigator	Subjects	Findings
Woolley, 1925	1 subject	Persistence of pattern of aggression, age 2 to 5 years
Cushing, 1929	Preschool	Persistence in perseveration
Washburn, 1929	Infants	Persistence in smiling during first year
Loomis, 1931	Preschool	Persistence in number of social contacts
Bayley, 1932	Infants	Persistence in crying responses
Green, 1933	Preschool	Persistence in frequency of group play
Brackett, 1935	Preschool	Persistence in laughing patterns
Jersild and Markey, 1935	Preschool	Conflict behavior similar for two test situations 1 year apart
Stutsman, 1935	Preschool, $N = 140$	High consistency ratings on traits and personality profiles for over 3 years
Allport, 1937	1 child	Prognosis based on patterns at 4 months borne out 2 years later
McGraw, 1939	Identical twins 1 pair	Behavior patterns of Johnny and Jimmy persisted from infancy to 6 years, when observation ceased
Gesell et al., 1939	Preschool, $N = 5$	A number of traits persisted from age 1 to age 5

tively constant throughout adulthood to old age. Arkin (1933) compared personality traits of individuals aged 25 to 40 with earlier characteristics revealed in case histories of the period 5 to 8 years. He reports that 100 per cent of the males were equally "emotional" at both age levels and that 67 per cent of the females were just as emotional in later as in earlier years. Intelligence, special endowments, social attitudes, and degree of initiative were of the same order in 67 to 100 per cent of the cases.

In another investigation, Roberts and Fleming (1943) studied persistence of traits in 25 precollege, college, and postcollege women. They found that persistence tended to exceed changes but reported large individual differences: 16 showed more, 6 equal, and 3 less persistence of traits than change. On the whole, the ratio of persistence to change approximated 3:2.

The fragmentary data available on old age suggest that certain traits tend to persist into the later years. Miles and Miles (1949), for example, state:

In personality appraisals by psychologic test methods, the evidence for persisting patterns throughout adult life is far greater and more significant than the evidence of age alteration in normal adults. When differentiated traits called neuroticism, self-sufficiency, introversion and dominance have been measured in adults from twenty to eighty, constancy in the decade to decade means is the

rule rather than the exception for both sexes. Individual differences in personality also occur throughout adult life . . . . At every age individual personality differences outweigh age tendencies [p. 100].

Individual Differences in Persistence of Traits. From an over-all view of the many studies in this field, it can be seen that persistence of traits is evidenced in varying degrees by different people. Furthermore, some traits tend to be more persistent than others. Most stable are the temperamental, emotional, and intellectual characteristics; least constant are the traits involving social relationships. The relative instability of the more social characteristics may be related to their specificity to given social situations. The Hartshorne and May (1928) studies, for example, indicated that an individual may be introverted or honest in one situation but extroverted or dishonest in another. It is therefore unwise to generalize concerning some personality characteristics.

Heredity and Environment. In view of the apparent tendency of many personality traits to persist from early childhood on, we might well ask, "Is personality, then, largely a matter of heredity?" Many investigations have been directed toward answering this question. Let us look at a few of them.

McGraw's (1939) study of Johnny and Jimmy should be especially helpful in throwing light on the problem, for Johnny and Jimmy were identical twins, reared in the same environment. Although they began life with similar hereditary components, their personalities differed. On the other hand, several classic studies of identical twins reared apart have reported striking similarities in traits which can be measured anthropometrically and less close resemblances in intellectual functions. On traits appraised by the Pressey Emotions Test; the Kent-Rosanoff Association Test, which measures peculiarities of associations; the June Downy Will-Temperament Test, which allegedly gauges speed, flexibility, forcefulness, and decisiveness as well as carefulness and persistence of reactions, no higher correlations were obtained between identical twins than between fraternal twins or siblings. Nevertheless it was found that total personality patterns of the identical twins were strikingly similar. In 5 out of 19 cases, the will-temperament profiles were almost identical (Newman *et al.*, 1937).

Studies of animals have suggested that hereditary factors may underlie certain types of behavior. Several investigators have shown that characteristics such as timidity, savageness, and general activity vary when heredity is changed even if environment is held constant (see Chapter 2).

Writers in the field of personality seemingly align themselves with one side or the other in the nature-nurture controversy. Sheldon (1942), for example, has spent many years attempting to classify personality types

according to varieties of physique, in which heredity presumably plays a dominant role. At the other extreme, men like Kardiner (1945) and Linton (1945) have tried to build a "basic personality" representative of a society on the assumption that personality is culturally determined. The conflicting findings of such studies are presumably a result of our limited instruments, which tap various facets inadequately and often call for subjective interpretation of equally subjective personal reports.

Perhaps the best approach to the personality problem is advocated by Breckenridge and Vincent (1949). They maintain that while certain personality traits change with the years, some remain relatively constant. These persistent traits may be regarded as the nucleus, or central core, of personality which lends stability to the structure. Such traits as temperament, intellectual factors, and certain physical capacities which form a part of this core are determined primarily by hereditary factors. On the other hand, interests, attitudes, and such traits as introversion or aggressiveness which appear to be less constant are influenced primarily by environment. In any event, present evidence suggests that, like any other aspect of development, personality depends on the interaction of both heredity and environment.

ADJUSTMENT AT VARIOUS AGE LEVELS

Throughout this text, we have emphasized the continuity of behavior—continuity from phylum to phylum, continuity from age to age, and continuity from normal to abnormal. Such continuity applies also to personality development. The optimally integrated, or "normal," personality sees the outer world as it is and directs his energies toward goals set and limited by his environment; the less well integrated may see the world in the light of his own biases, may set less well-defined and less realistic goals, and may dissipate varying amounts of energy in his wavering attempts to reach them. Both of these are "normal." Further along the continuum, however, we find the disintegrated, or disoriented, personality, labeled *psychotic*. The psychotic is no longer able to care for his own needs. He fails to see the world in realistic terms and therefore cannot align his goals with reality. His misguided energies are thus of little practical value. In this sense, the psychotic fails to adjust to his environment. Most of us are neither optimally adjusted nor psychotic. Like the Englishman of the story, we "muddle through," modifying both our goals and our methods of achieving them from time to time, but retaining our grip on reality.

The average person whom we usually call "well adjusted," or normal, is happy, contented, and relatively free from various disturbing anxieties, and his behavior conforms to standards set by his culture. He can deal adequately with the various problems of life as they arise.

Adjustment as Revealed by Incidence of Psychoses and Suicides. We lack quantitative data on well-adjusted people of various ages. However, some idea of how general adjustment is related to age may be obtained by examining the negative data, that is, the incidence of mental disorders and suicides for different age groups. Age changes are summarized in Fig. 111.

Psychoses. Curve *A* of Fig. 111 shows the incidence of all mental disorders from age 14 through age 70. Prior to the teens, the incidence of
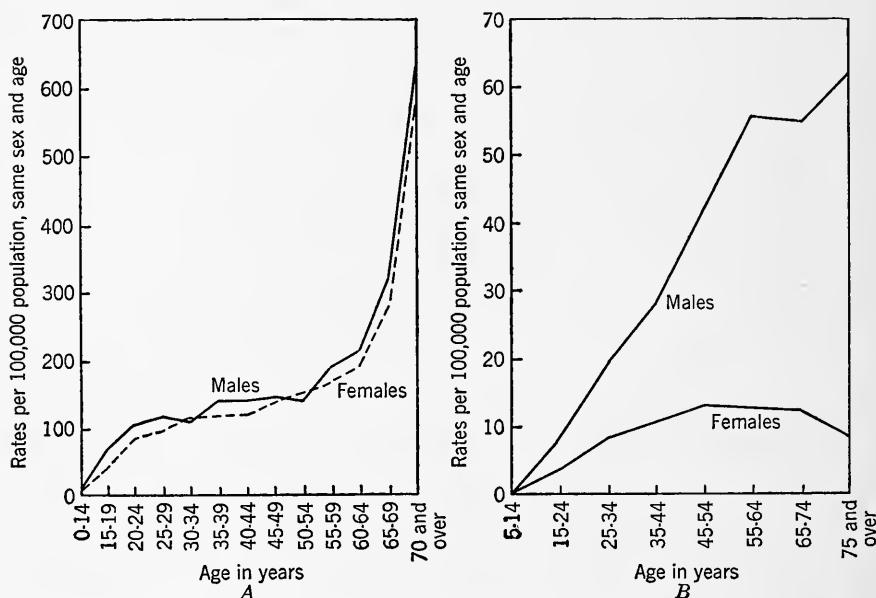
Fig. 111. Relationship between age and incidence of mental disorders (*A*) and incidence of suicides (*B*). (*Based on data from Pollack and U.S. Bureau of the Census. From L. A. Pennington and I. A. Berg (Eds.). An introduction to clinical psychology. New York: Ronald, 1948. P. 231. By permission of the publishers.*)

psychoses is quite low, indicating relatively good adjustment. From the teens to early 20's, the incidence rises rapidly to approximate 140 cases per 100,000 population. This picture remains fairly constant to the sixtieth year, when another abrupt increase brings the frequency to 600 cases per 100,000 population by the age of 70. Age curves for individual psychoses differ from the over-all curve. Involutional psychoses, for example, first appear during the 30's and reach a peak in the early 50's. On the other hand, schizophrenia and manic-depressive psychoses appear as early as the teens, with peak incidence occurring in the fourth decade.

What causes psychoses at any age and what precipitates more breakdowns at some ages than at others is of course a vital question, and hence

is frequently studied. Several investigations point to factors which may be at least partly responsible for the increased incidence in later years. Semrod and McKeon (1941) observed that most patients admitted to mental hospitals after the age of 70 had long histories of personality difficulties and financial dependency. An important precipitating factor in the final breakdown was the removal of protective support when the home environment was disrupted. Klopfer (1944) reported that racial and ethnic background seemed not to be involved but that life situations and experiences contributed to breakdown. Titley (1936) found that certain traits such as narrowness of interests, difficulty in adjusting to change, limited capacity for sociability, rigid adherence to high ethical standards, proclivity for saving, reticence, anxiety, stubbornness, overconscientiousness, and meticulousness were common to 10 elderly psychotic patients studied. Prout and Bourcier (1940) reported that among problems which seem to heighten emotional stress during later maturity are (1) support of family, (2) social and communal obligations, (3) economic insecurity, (4) biologic involution, (5) curtailment of physical activity, and (6) fears over sexual potency. These difficulties precipitated mental disorders in some cases; in others they contributed to generally poor adjustment.

At this point it might be desirable to emphasize that the social factors listed by the various investigators are not the causes of psychoses; they are simply precipitating factors. Neither poverty, insecurity, nor other misfortunes can, by themselves, cause psychoses. Many a man is poor yet retains his sanity; many lack security yet reach old age without nervous breakdowns; many lose family members and friends yet adjust to the loss. We do not know the cause of psychoses. Many investigators, however, believe that there is a contributory hereditary factor.

Suicides. Curve *B* of Fig. 111 shows the age trends in incidence of suicides. Again, this particular evidence of maladjustment is almost nonexistent prior to the age of 14 but increases rapidly thereafter, especially among males. In view of the striking sex difference in suicide rates, let us examine the two curves separately. In males, the incidence increases so abruptly that by the age of 25 to 34 roughly 19 cases per 100,000 population commit suicide, and by the seventy-fifth year 62 cases per 100,000 do so. In females, the picture is far less drastic. By 25 to 34 years, only 8 cases per 100,000 population are reported, and by 45 to 54 years 13 cases. In marked contrast to males, the incidence then decreases to 8 per 100,000 by the age of 75.

Suicide rates furnish an excellent illustration of the contribution of social factors to maladjustment. The differential rates in the two sexes strongly suggest that the economic burdens placed on the males in our society contribute in some degree at least to incidence of suicide. It is well established that suicide rates are correlated with economic trends

throughout the country (Jones and Kaplan, 1945). They were higher, for instance, in 1930 after the Wall Street market crash than in 1940.

Adjustment as Revealed by Incidence of Nervousness and Neuroticism. Pertinent to our present discussion are the data assembled on incidence of nervousness, for "nervous" people are maladjusted to some degree. Hamilton (1942) recorded the number of patients of different ages who came to a physician with complaints of nervousness. He found that the incidence remained relatively constant through the 20's, 30's, 40's, 50's, and 60's. Other investigators have used questionnaires and various personality tests for measuring neuroticism. These, also, have reported that incidence of neuroticism remains fairly constant between 20 and 60 years of age (see Shock, 1951). There are indications, however, that neuroticism increases significantly between the sixth and eighth decades (Willoughby, 1937, 1938).

Adjustment as Revealed by Happiness. Happiness is a good "thermometer" of adjustment. Table 36 shows the percentages of elderly people living in New York and Iowa who, in retrospect, consider the various age periods indicated as their happiest. People of both states agree that the period between 25 and 45 years was the happiest; the youthful period from 15 to 25 years ranked second, while old age was considered happiest by only 5 per cent of the subjects in either state.

The reasons given for considering young adulthood the happiest are interesting. According to Morgan (1937), over half of the elderly subjects designated this period because of the existence of family life and family relationships; others selected it because of freedom from various responsibilities and because of keen interest in their work. It would be interesting, indeed, to know how they felt about such relationships and responsibilities at the time when they actually existed. Studies based on retrospection do not always provide the best of evidence, and although happiness is a good indicator of good adjustment, idealization of past situations is not an accurate measuring stick.

Although few elderly people consider the later years their happiest, they may still be happy. Morgan (1937) made a careful analysis of the characteristics which significantly differentiate the happiest from the unhappiest people over the age of 70. She found that happiness in old age is related to having plenty to do every day and ability to do some kind of work well; good health; development of hobbies and special interests in early life; membership in clubs, lodges, and unions; having friends in the immediate neighborhood; and possessing more than an elementary education. Of all these, the most important to maintenance of happiness are keeping busy and actively participating in some activity.

So far, we have been concerned with over-all adjustment throughout the life span. Let us now look at the nature of adjustment during cer-

tain so-called critical periods such as puberty, the menopause, and postretirement.

TABLE 36. PERCENTAGE OF ELDERLY PEOPLE CHOOSING EACH OF THE VARIOUS PERIODS OF LIFE AS HAPPIEST*

Age groups	New York (Morgan) $N = 370$	Iowa (Landis) $N = 450$
Childhood (5–15 years).....................	14.5	11.1
Youth (15–25 years)........................	18.9	19.3
Young adulthood (25–45 years).............	49.1	51.4
Middle age (45–60 years)..................	12.4	5.8
Later life (60 and up)......................	5.1	4.7
Undecided or no data.......................	—	7.7

* From Kuhlen, R. G. Age differences in personality during adult years. *Psychol. Bull.*, 1945, **42**, 343. Quoted by permission.

Adjustment at Puberty. Two specific age periods are popularly considered times of "storm and stress," especially prone to maladjustments. The first is puberty for both sexes; the second, the menopause for females. Probably the belief that these physical transition periods are accompanied by emotional upheavals is based on the knowledge that glands affect emotions and that glandular changes occur at these times. Both of these initial premises are true. The conclusion, however, needs scrutiny.

What experimental evidence have we to justify the view that the circumpubertal years are fraught with anxieties and tensions? Most research findings contradict—or at least fail to support—this view.

As we have already observed, the incidence of mental disorders and suicides is low during childhood. Although incidence increases during adolescence, no peak is reached at puberty (see Fig. 111A and B). In fact, the highest incidence appears some years later when the individual leaves school and faces adjustment to the working world. Since the data presented earlier concern extreme forms of maladjustment, let us examine some of the less drastic manifestations such as anxieties, worries, and personal problems. One investigator in this area reports that the total number of worries actually decreased from the age of 12 through adolescence in both males and females. Incidence of personal problems showed the same trend (unpublished data by Pressey, cited by Kuhlen, 1952a). Again, it has been noted that incidence of problem behavior such as sulking, temper tantrums, impertinence, and fighting showed no increases at puberty (Blatz *et al.*, 1937). Studies by Mead and other anthropologists reveal an absence of "storm and stress" in adolescents of primitive societies. We may therefore conclude that the period of life around puberty is

not in itself unduly stressful, although it may be so in cases where childhood training has been deficient or faulty.

Adjustment to Menopause. The time of the menopause or "change of life" is also popularly believed to be a period of increased anxieties, nervousness, tension, and emotional instability. We may again ask, Does experimental evidence support such a view?

We have already cited the study of Hamilton (1942), which revealed no age changes in incidence of "nervous problems" between 20 and 60 years. It is interesting that the incidence should be the same in the 40's, when the menopause typically occurs, as in the 30's and 50's, when it seldom occurs. In addition to this lack of increased incidence of nervousness, Willoughby (1937) reported that this period is the calmest time of life. In reviewing the literature on personality changes at the menopause, Kuhlen (1945) states that

. . . none of the studies of personality here reviewed has given any suggestion of increased disturbance during that period. This would seem to belie the generally accepted notion of marked emotional changes during the menopause. . . . The only conclusion warranted at present is that more research is needed; certainly dogmatic statements regarding stress at this age are inappropriate. It is even possible that the "storm and stress" of the menopause will turn out to be the same type of will-o'-the-wisp as the traditional but never really demonstrated "storm and stress" of adolescence [pp. 344–345].

Adjustment in Old Age. Since happiness is a thermometer of good adjustment, we can anticipate much of the evidence in this section from earlier comments and citations. It is only within recent years that any extensive and thorough investigations of adjustment of elderly people have been made. One of the most extensive was conducted by Cavan *et al.* (1949), who gave an attitude inventory to over 1,000 persons aged 60 to 100 years. This inventory contained items dealing with feelings of happiness and usefulness and with whether the subject wished to continue living. The results of the survey are recorded in Table 37. We see that the majority of people between 60 and 64 years feel happy and useful, have a zest for life, and are interested in a variety of activities. Such favorable attitudes decline rapidly, however, and by the 90's only a small percentage express such feelings. The course of decline is the same for males and females except with regard to usefulness. Roughly 50 per cent of women in their 90's still feel that they are useful; only 20 per cent of the men feel this way. Undoubtedly, household activities contribute to the women's views in this respect. On over-all performance, the adjustment scores indicated in Table 37 gradually decrease from the age of 60 on.

Factors Differentiating Well-adjusted from Poorly Adjusted Old People. Although many old people are poorly adjusted, this situation is neither

TABLE 37. DECLINE IN ADJUSTMENT ATTITUDES IN ELDERLY PEOPLE*

Attitude indicated	Age period and percentage with given attitude						
	60-64	65-69	70-74	75-79	80-84	85-89	90-94
Males							
Attitude of happiness (high scores).....	50	44	38	33	33	40	40
Attitude of usefulness (high scores).....	84	71	82	74	71	50	20
Great zest for life.....................	49	47	38	39	44	19	17
Lack of interest in life.................	4	12	13	10	5	17	20
Median adjustment score on attitude inventory...........................	52	50	53	52	51	48	44
Females							
Attitude of happiness (high scores)......	40	38	27	26	17	21	8
Attitude of usefulness (high scores).....	88	73	71	68	58	41	50
Great zest for life.....................	43	39	35	41	26	18	8
Lack of interest in life.................	6	14	10	19	11	25	31
Median adjustment score on attitude inventory...........................	52	51	50	50	44	43	46

* From Cavan, R. S., Burgess, E. W., Havighurst, R. J., and Goldhamer, H. *Personal adjustment in old age.* Chicago: Science Research Associates, 1949. P. 59. By permission of the publishers.

universal nor peculiar to old age. Several investigations have been directed toward discovering what factors make for good adjustment in later life.

Two of the earliest students in this field reported that good adjustment was associated with good health and with something to occupy the time— for example, hobbies, interests, and social contacts (Morgan, 1937; Landis, 1940). It was also pointed out that the average elderly woman was happier than the average man, perhaps because men have less to do after retirement (Landis, 1940).

More recent investigations generally corroborate these findings. Havighurst and Shanas (1950) report on a very interesting group of retired government workers and professional men who had formed an organization called The Fossils' Club, chosen for study because the members seemed to be much better adjusted than the average retired man. They found that the unusually good adjustment was due to (1) financial security, (2) late retirement, and (3) good living arrangements. Pressey and Simcoe (1950), who investigated an average group, extended these contributing factors to include close family ties and friendships, a positive attitude to religion expressed by church attendance, extent and variety of interests, and good health.

Conversely, it has been shown that maladjustment is associated with poor health, lack of interests and hobbies, financial insecurity, feeling that work is a burden, and failure to attend church. Poor adjustment is aggravated by low education level as well as by unmarried status and divorce (Landis, 1940). Among such contributing factors, the consensus of findings seems to point to lack of strong and varied interests as the most important. Living in the past—*e.g.*, hoarding souvenirs and relics and reminiscing—also appears to hinder good adjustment (Conkey, 1933).

In summary, then, good personal adjustment in later life apparently depends on (1) good health, (2) pleasant social relations with relatives and friends, (3) good living arrangements, (4) financial security, (5) varied interests, and (6) religious interests. In conclusion, we must also emphasize that good adjustment in old age is largely a product of good adjustment in earlier years and that similar factors contribute in both early and later life.

VISUAL AIDS

The motion pictures listed below and on the following pages can be used to supplement much of the material in this book. It is recommended, however, that the films be reviewed first in order to determine their suitability for a particular group. Immediately following the title of each film are the names of its producer and distributor (sometimes the same), and these individuals and organizations are identified in the list of sources at the end of the bibliography. In many instances, the films can be borrowed or rented from local or state 16-mm film libraries. (A nation-wide list of these local sources is given in *A Directory of 2660 16mm Film Libraries*, available for 50 cents from the Superintendent of Documents, Washington 25, D.C.) All the motion pictures are 16-mm films and, unless otherwise indicated, are sound and black and white.

This bibliography is a suggestive one, and film users should also examine the catalogues (free on request) of the following institutions which have specialized libraries of films on various aspects of human development:

International Film Bureau, 57 E. Jackson Blvd., Chicago 4

New York University, 26 Washington Pl., New York 3

Pennsylvania State University, Psychological Cinema Register, State College, Pa.

State University of Iowa, Bureau of Visual Instruction, Iowa City, Iowa

Adolescent Development (MP series, McGraw, 15–20 min each). Five films, correlated with Elizabeth Hurlock's text of the same title, explaining various phases of adolescence. Titles of the films, each one with a follow-up filmstrip, are:

The Meaning of Adolescence
Physical Aspects of Puberty
Age of Turmoil
Social-Sex Attitudes in Adolescence
Meeting the Needs of Adolescence

Ai-Ye (MP, Brandon, 28 min color). Universal story of mankind's voyage through life as illustrated by scenes photographed along the

Pacific Coast of South America. Accompanied by drum and chant music; no narration.

Angry Boy (MP, IFB, 33 min). Traces via psychiatric care the reasons for a boy's thefts in school and relates them to emotional disturbances in adolescence.

Beginning of History (MP, BME/IFB, 46 min). Pre-history of Great Britain with the theme of the continuity of human life and culture, the continuum of past and present, and the relationships between events of thousands of years ago and today's peoples. Also available as three separate films entitled *Stone Age, Iron Age,* and *Bronze Age.*

Cell Division (MP, Phase, 11 min). Shows by microphotography the development of a living cell during a 21-hour period, including dissolution of the nuclear wall, spindle formation, assembly and separation of the chromosomes at the equatorial plate, division of the parent cell, and formation of new cells.

Cells and Their Functions (MP, Athena, 14 min). Shows by photomicrography and time-lapse photography the activities of a number of kinds of cells, including mitosis, beating cilia, blood cells engulfing bacteria, and proliferation of tissue.

Child Development (MP series, EBF, 10–11 min each). Based upon research studies of Dr. Arnold Gesell at the Yale Clinic of Child Development, the films portray behavior patterns of normal children at various developmental ages. Titles are:

Baby's Day at 48 Weeks
Baby's Day at 12 Weeks
Behavior Patterns at One Year
Early Social Behavior
From Creeping to Walking
Growth of Infant Behavior: Early Stages
Growth of Infant Behavior: Later Stages
Learning and Growth
Life Begins
Posture and Locomotion
Thirty-six-weeks Behavior Day

Children Growing Up with Other People (MP, BME/UWF, 30 min). Illustrates stages in the growth of children and their adaptability to the world in which they live.

Children Learning by Experience (MP, BME/UWF, 40 min). Illustrates ways in which children learn.

Children's Emotions (MP, McGraw, 22 min). Illustrations of the major emotions of childhood—fear, anger, jealousy, curiosity, and joy.

Circulation (MP, UWF, 16 min). By animated diagrams explains the systematic and pulmonary circulation of the blood, including the structure and functions of heart, lungs, arteries, veins, and capillary network.

Crawling and Creeping (MP, IFB, 13 min silent). Illustrates the normal developmental sequence of crawling and creeping in the human infant.

Development of Locomotion (MP, Calif, 10 min silent). Developmental sequences in a series of children from 6 to 15 months of age showing various methods of locomotion.

Development of the Nervous System in Vertebrates and Invertebrates (MP, Brandon, 30 min silent). Traces the development of the brain of fish to the brain of man.

Eight Infants: Tension Manifestations in Response to Perceptual Manifestation (MP, NYU, 42 min silent). Behavior of infants 18 to 25 weeks of age before and after prolonged perceptual stimulation.

Embryology of Human Behavior (MP, AAMC/IFB, 28 min color). Explains and illustrates general principles of human development and the unique variations among individuals. Traces the processes of behavior through sequences of eye-hand coordination of growing children.

Endocrine Glands (MP, EBF, 11 min). Points out the effects of improper functioning of the endocrine glands and the causes and remedies of faulty glandular actions.

Experimental Psychology of Vision (MP, IFB, 16 min silent). Chief phenomena of visual perception including phi phenomenon, optical illusions, color constancy, eye movements, perception span, and digit span.

Factors in Depth Perception (MP, PCR, 14 min silent). Illustrates such factors as interception, interposition, distinctness of objects, relative motion, etc.

Fears of Children (MP, IFB, 30 min). Parent-child situation in which the mother tends to coddle her 5-year-old son and the father expects too much of him. Explains how the conflict magnifies the child's fears.

Fingers and Thumbs (MP, Lib Films, 20 min). Traces the development of man's hands. Produced by Strand Film Co., under the supervision of Julian S. Huxley.

Frustrating Fours and Fascinating Fives (MP, CNFB/McGraw, 22 min). Characteristic behavior patterns in children 4 and 5 years of age and the changes that occur during the year.

Functions of the Nervous System (MP, PCR, 13 min). Describes central nervous system; cranial, cervical, thoracic, lumbar, and sacral connections; sympathetic ganglia; sense organs; and mechanism of muscular coordination.

Growth of Motor Behavior (MP, EBF, 15 min silent). Traces the development of motor control from birth to age five. Produced at the Yale Clinic of Child Development.

He Acts His Age (MN, CNFB/McGraw, 15 min color or b&w). Survey of typical behavior patterns of children from the ages of 1 to 15.

Heredity (MP, EBF, 11 min). Explains with animated charts and animal picturization the Mendelian laws of inheritance.

Heredity and Environment (MP, Coronet, 10 min). Overview of cultural inheritances, genetics, environmental influences, and their interrelationships.

Human Growth (MP, Brown, 19 min color). Traces human growth and development of the organism from birth to adulthood, emphasizing the difference in male and female structural development at different ages.

The Human Heart (MP, Brandon, 10 min). Describes with diagrams and experiments the mechanics and functions of the heart.

Introduction to Combat Fatigue (MP, USN/UWF, 31 min). Analyzes fear and relates the symptoms of combat fatigue (startled reaction, irritability, nightmares, tension, etc.) to their causes through flashbacks of simulated action in a combat area. Two versions available—one for patients, one for doctors.

Judging Emotional Behavior (MP, Churchill, 20 min). Motion-picture test designed to measure the sensitivity of individuals to the emotions of others. Ten sequences are shown in which two people react as if certain events described by a narrator were happening to them. Made for use in psychology classes.

Life with Baby (MP, MOT/McGraw, 18 min). Summary of film studies of the physical and mental growth of children ages 1 to 6 done at Yale University under the direction of Dr. Arnold Gesell.

Mechanics of the Brain (MP, Brandon, 60 min silent). Demonstrates the fundamental processes of the psychology of the nervous system, based upon the experiments of I. V. Pavlov.

Mental Mechanisms (MP series, CNFB/McGraw). Five films portraying through case studies some problems of adults and their roots in early childhood and family relationships. Titles and running times of the individual films are:

Breakdown (40 min)
Feeling of Hostility (27 min)
Feeling of Rejection (23 min)
Feelings of Depression (30 min)
Over-dependency (32 min)

Mental Symptoms (MP series, CNFB/McGraw). Nine films prepared for the Canadian Department of National Health and Welfare portraying different mental symptoms indicated by the film titles, as follows:

Schizophrenia: Simple-type Deteriorated (11 min)
Schizophrenia: Catatonic Type (12 min)
Schizophrenia: Hebephrenic Type (13 min)
Paranoid Conditions (13 min)
Organic Reaction-type: Senile (10 min)
Depressive States: 1. (12 min)
Depressive States: 2. (11 min)
Manic State (15 min)
Folie à Deux (15 min)

The Nervous System (MP, EBF, 11 min). Elementary demonstration of the structure and function of spinal cord, medulla, mid-brain, thalamus, cerebrum, and membrane theory of conduction.

Personality Development (MP series, EBF, 10 min each). Four films portraying stages in the personality development of children. Titles are:

Answering the Child's Why
Baby Meets His Parents
Helping the Child to Accept the Do's
Helping the Child to Accept the Don't's

Principles of Development (MP, McGraw, 17 min). Outlines the fundamentals of child growth and development, including general principles and individual variations. Correlated with text, *Child Development*, by Elizabeth B. Hurlock.

Social Development (MP, McGraw, 16 min). Analysis of social behavior at different age levels and the reasons underlying changes in behavior patterns as a child grows. Correlated with text, *Child Development*, by Elizabeth B. Hurlock.

The Steps of Age (MP, IFB, 25 min). Emotional problems and interpersonal relations within the family faced by a woman of 62 who must retire from her job. Sponsored by Mental Health Film Board and South Carolina Department of Health.

Techniques of Anthropometric Measurement (MP, Calif, 12 min silent). Shows procedures of taking 14 different measurements, illustrations of children with different body builds, and growth curves.

The Terrible Twos and the Trusting Threes (MP, CNFB/McGraw, 20 min). Study of child behavior at 2 and 3 years, and the changes that occur during the year.

LIST OF SOURCES

AAMC—Association of American Medical Colleges, Medical Audio-Visual Institute, 185 N. Wabash Ave., Chicago 1.
Athena—Athena Films, Inc., 165 W. 46th St., New York 19.

BME—British Ministry of Education, London.

Brandon—Brandon Films, Inc., 200 W. 57th St., New York 19.

Brown—E. C. Brown Trust, 220 S.W. Alder St., Portland 4, Ore.

Calif—University of California, 2272 Union St., Berkeley, Calif.

Churchill—Churchill-Wexler Film Productions, 801 N. Seward St., Los Angeles 28.

CNFB—National Film Board of Canada, Ottawa (films distributed in U.S. by McGraw Hill Book Co.).

Coronet—Coronet Films, Inc., Coronet Bldg., Chicago 1.

EBF—Encyclopaedia Britannica Films, Inc., Wilmette, Ill.

IFB—International Film Bureau, 57 E. Jackson Blvd., Chicago 4.

Lib Films—Library Films, Inc., 25 W. 45th St., New York 19.

McGraw—McGraw-Hill Book Company, Inc., Text-Film Dept., 330 W. 42d St., New York 36.

MOT—March of Time Forum Films, New York (films distributed by McGraw-Hill Book Company, Inc.).

NYU—New York University, Film Library, 26 Washington Pl., New York 3.

PCR—Psychological Cinema Register, Pennsylvania State University, State College, Pa.

Phase—Phase Films, P.O. Box 423, Ross, Calif.

USN—U.S. Dept. of the Navy, Washington 25, D.C. (films distributed by United World Films.).

UWF—United World Films, Inc., 1445 Park Ave., New York 29.

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